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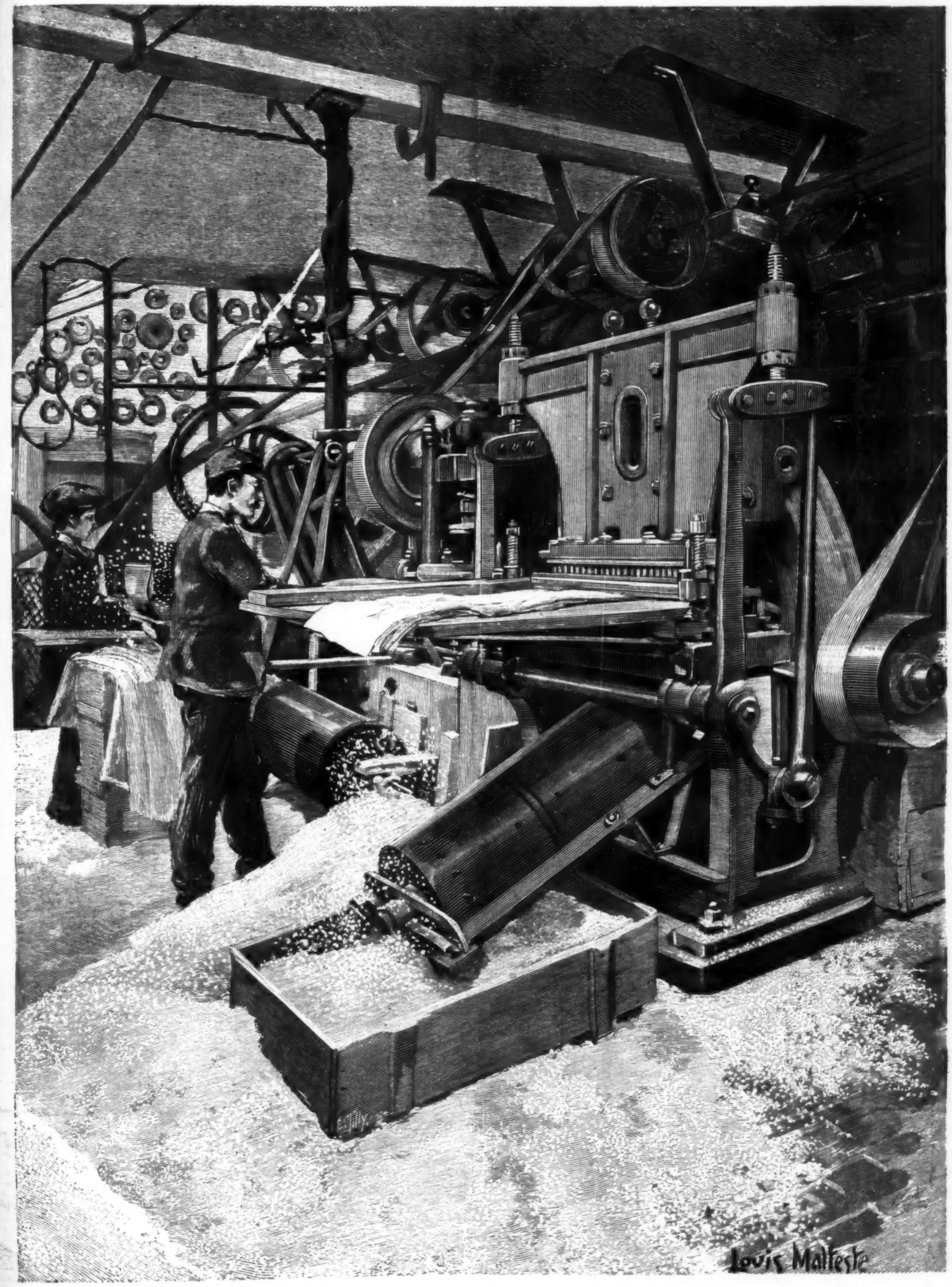


MACHINERY FOR THE MANUFACTURE OF CONFETTI.

CONFETTI AND SERPENTINES.

A GRATEFUL people will be very much embarrassed on the day that it desires to erect a statue to the inventor of confetti. It has not as yet been possible to agree as to his name, and it is not very probable that this important question will be elucidated hereafter. But a single point has been acquired by history, and that is that the first confetti were thrown in the Paris Casino in the month of January, 1891. They met with extraordinary success, and all those who were present at this memorable soiree celebrated with tearful eyes the renaissance of French gayety. On the next day a thoughtful man cut up all the paper trimmings obtainable, and the confetti, applauded at the opera, soon received their definitive consecration upon the Boulevard. But what confetti they were! To use the words of the present manufacturers, the art was in its infancy. These little disks of paper, of unequal thickness, often stuck together, and, full of dust, gave the impression of a barbarous industry. One had not even dreamt of varying their tints in order to obtain those plays of colors that are now so much appreciated by amateurs.

The apparatus, moreover, which was quite simple, was speedily improved, and the machine represented herewith now seems to respond to every exigence. In its essential arrangements, it differs but little from the primitive model. A sort of power stamper, formed by the juxtaposition of 572 cylindrical punches, moves between two uprights. These punches, which are of tempered steel, are solid, and terminate in a cutting edge that fits into the corresponding apertures of a horizontal plate upon which is placed the paper that is made to move forward progressively.

This system of punches penetrates a thickness of 36 sheets and produces 55 pounds of confetti an hour.

The plate, which is 35 inches in width, is but about 2¼ inches in thickness. As the sides of the apertures slope slightly, the confetti drop out without difficulty, but many remain stuck together. At first, these were separated by hand, which sensibly increased the net cost, but now the work is done mechanically. Upon coming from the plate, the confetti are collected by a system of buckets analogous to those of dredging machines, which empty them into a drum provided internally with helices that have a very rapid motion. The little disks of paper separate in a few instants, part with their dust and fly into a receiver, whence they are removed by a shovel and packed in large grain bags.

A complete machine, set up in place, costs from one thousand to twelve hundred dollars. It requires three operatives to serve it. A woman folds the paper to the width of the plate, a child presents it to the machine, and another child gathers the confetti.

Under such circumstances, the cost of manufacture is a mere bagatelle alongside that of the crude material; in fact, the utilization of waste paper had to be given up at an early period. Aside from the fact that it became inadequate to supply the new industry, it did not permit of giving the confetti the artistic stamp dreamed of by the more progressive. These latter proposed to themselves the luxury of cutting special paper, and were soon giving the Pereire and Darblay mills orders that were larger than those of a daily journal. The colored paper designed to be converted into "silk" confetti costs them about $3.50 per hundred pounds, while glazed paper is dearer. The white paper, which is worth about 80 cents less per hundred pounds, permits of reducing the net cost of the mixtures. Finally, the waste, which was hardly 20 per cent., has been reduced to zero by an ingenious spacing of the punches. The interval between the four disks forms a star which is mixed with the other confetti.

In the beginning, the profit was large. The confetti, offered at first at eighteen cents a pound, remained for quite a long time at fourteen cents. At a certain Sunday opening of the fair of Place du Trone, one merchant alone sold 5,500 pounds at this price in the space of two hours. There was a great excitement among the fakirs, who were distressed to see so much money squandered to their prejudice. Bidel himself was anxious about his lions, and the prefecture of police forbade the play of confetti in order to protect the rights of gingerbread. After various fluctuations, the wholesale price dropped to five cents, and it seems difficult for this limit to be crossed. It is true that street venders are seen offering their merchandise at three and a half cents, but the confetti that they sell are made from old hand bill paper bought for about a cent or a cent and a half a pound by second-class houses that are not haunted by the fear of microbes. The profit of the middlemen has necessarily diminished in the same proportion. The two pound bag is resold for hardly more than 13 or 14 cents. But they make up for this in quantity, since every carnival day now represents for Paris alone a minimum consumption of 330,000 pounds of confetti. The profit, however, is still handsome for the street vender, who retails the fifty or sixty glasses contained in two pounds at one cent each.

At one time the reputation of confetti seemed to be exhausted. The Parisians abandoned it for the serpentine and the peafowl feather. Our manufacturers receiving somewhat of a setback, then attacked foreign countries. The confetti, shipped to the four quarters of the globe, were adopted by the most diverse civilizations, and at present the exportation reaches 888,000 pounds of confetti a year. It is South America that absorbs the most of them. The showers of confetti have there replaced the strewing of flowers in religious processions, and it is hoped that ere long funeral confetti will be introduced into these sunny regions. Afterward comes Belgium. Upon the slightest occasion, Brussels orders 20,000 pounds of the little paper disks by telegraph. Russia, Germany and Italy are beginning to acquire a taste for this sort of diversion, but England remains rebellious.

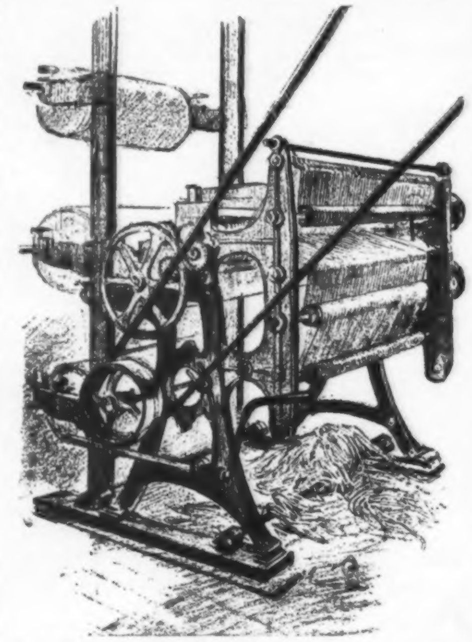
Of course, every country demands a mixture corresponding to its national colors. The Russian confetti, yellow and black, produce quite a singular effect. Golden confetti, at about a dollar a pound, are manufactured especially for the Khedive and Sultan. Forbidden at Paris by reason of the poisonous dust that they scatter, they menace the health of the harem as well as the equilibrium of the Oriental finances.

In order to amuse all this world, three or four large manufactories, of Belleville, are run the whole year. The largest one, that of Mr. Charles Levy, employs fifty persons and produces 3,300 pounds of confetti a day. In addition to these manufacturers, a number of workmen owning a stamping press cut out confetti in their moments of idleness and make quite an addition to the general production, which may be estimated at 3,300,000 pounds per annum. They thus create a supplement of resources of thirty or forty dollars which often spares them several weeks of misery. Let this be to the philosopher and the dilettante the excuse for confetti.

Of a more graceful effect, and not lending itself to the same brutality, the serpentine is less easily wasted. The manufacture was at first quite summary, a roll of paper of a certain thickness having been simply cut in strips. But the section was wanting in sharpness, and the ribbon, unequally taut, unwound without grace.

The new machine, of which our engraving shows the general aspect, is conceived in a totally different manner. It cuts but one thickness of paper at a time. The sheet passes between two cylinders, each provided with seventy-five circular knives that cut it without any waste into as many ribbons, which wind around an equal number of mandrels. When the serpentine is of the desired length, a clockwork movement, regulated at will, stops the machine. The strips are cut and one removes the seventy-five little rolls, whose extremity is fixed with a little glue.

The serpentines thus obtained are of perfect regularity. They are manufactured of several sizes. The smallest, 39 feet in length, are 2 inches in diameter, weigh 150 grains, and sell at about two dollars a thousand. The usual model is that of 80 feet, weighing 300 grains and costing four dollars a thousand. The tricolored serpentine, the winding of which is done in three separate operations, costs forty cents a thousand more. All countries order it along with their national serpentine. The success of these rolls of paper in foreign countries is equal to that of the confetti. England buys them for decorating her Christmas trees.



MACHINE FOR THE MANUFACTURE OF SERPENTINES.

The total production reaches about four million rolls, half of which are exported.

The carnival of 1895 saw the advent of a new plaything. The horrid couch grass brush that an endeavor was made to push two years ago was replaced by a tuft of strips of paper attached to the end of a reed pipe. The Parisian found it very amusing to tickle his neighbor and be tickled himself with this device. So he is already occupying himself with rendering this brush in its infancy as artistic as the confetti.—L'Illustration.

[FROM ENGINEERING.]

THE MANUFACTURE OF MARGARINE.

AN invitation, at afternoon tea, to partake of bread and margarine would not be received altogether as an act of hospitality in English middle-class society. The substance is regarded as an adulterant—something that is cheap and probably nasty. It is usually "made in Germany," or, at any rate, on the Continent, and the British matron has profound misgivings regarding foreign methods of preparing food. The legislature has stamped it as a criminal offense to sell margarine for butter, and in doing so has marked it with the brand of inferiority. It is not kept in the better-class shops, its sale being confined to those who have to consult the state of their purses, and not their tastes, in their marketings. Even in the poorer neighborhoods it has to take an inferior position at the back of the shop, while cheap butter, often of execrable flavor, is put in the window.

Yet were the facts concerning the manufacture of margarine properly known and appreciated, the whole of the prejudice against it would disappear. We do not suggest that it would rank equally with really good butter, but it would be judged on its merits, and would take a position somewhere among the medium qualities. The scrupulous cleanliness of its manufacture, and the uniformity of its quality, are points that tell in its favor, as compared with butters made in cottages and small farmhouses. These latter may, or may not, be free from impurities gathered from dirty and unsanitary surroundings; they are usually collected by merchants and worked up together, and it is scarcely conceivable but that some of the consignments are not wanting in the matter of cleanliness. Large quantities of cheap butter are used in cookery, and for this purpose margarine is excellently adapted. The beef suet from which it is made is not an objection to its use, since dripping and lard are freely used in the kitchen, while the vegetable oil it contains aids in the formation of puff pastry, which is alike the ambition and the despair of the ordinary cook.

We have lately had the opportunity of inspecting the working of Mr. Otto Monsted's margarine factory at Southall, near London, and have carried away a very vivid appreciation of the rigorous cleanliness that is enforced in all departments. Not only are there the usual precautions and rules that would suggest themselves to everybody, but the entire process and plant is surrounded by conditions which seem designed to elevate and dignify it in the eyes of the workpeople. In addition to abundant light and ventilation, there is a lavish expenditure on decoration and architectural embellishment. Roofs, floors and walls are not merely parts of the structure, but each is rendered pleasant to gaze upon. Mosaic pavement, delicately tinted glazed bricks in blended colors, and highly polished boards convert the spacious sheds into halls, and give rise to the feeling that dirt and slovenliness would be sacrilegious within them. Linen garments are provided for all the workpeople, and are washed on the premises in a steam laundry, so that there is no excuse for soiled attire. The outdoor dress of the operatives has to be left in a separate building, in which is a dining room of very handsome proportions, with parquetry floor, wainscoted walls and open timber roof. It seems as if the designer of the premises had set himself to inculcate in the workpeople a high respect for themselves and for their work, by placing them and their occupations in surroundings on which money had been lavished in the matter of design and decoration.

Next to light and ventilation, the most important factor in cleanliness is ample space, and it is found in abundance in the Southall factory. The site occupies 16 acres, and although only a small part of this is covered with buildings, yet these are of large size. They are arranged so that the materials go through the works without being touched by hand. The machines are spaced wide apart, with ample alleyways all round. Water is found in abundance on the ground, and is raised from 32 Abyssinian wells arranged in two rows, and connected by pipes laid underground, the supply being equal to 10,000 gallons an hour. Sidings for the Great Western Railway run alongside the building, delivering coal and other raw materials, and taking away the margarine, of which the factory is capable of producing 50 tons a day.

The making of margarine is simple enough in its general features, although it needs care and experience to carry it out successfully. The materials are oleomargarine, nut oil and milk. The first is beef suet from which the insoluble stearine has been expressed by pressure. It comes from large slaughter yards, like those at Birkenhead and also at Chicago. In appearance it resembles dripping, and is by no means unpleasant to the taste. It is packed in casks, and when these are opened the solid block that comes out is scraped to remove any dirt that may be adhering to it. It is then broken up by wooden shovels and shot into a tank jacketed with hot water. There are 16 of these tanks, each about 8 feet by 5 feet by 5 feet 6 inches deep, and capable of holding 3½ tons. The melting is expedited by mechanical stirring, and all impurities that show themselves are carefully skimmed off. The vegetable oil needs no preliminary treatment; it is the product of tropical nuts, and is poured into tanks to be drawn off as wanted. The milk arrives daily in the usual railway churns, and is so important a constituent that it is stated 5,000 gallons will be required each morning when the works get to their full output of 50 tons of margarine a day. The milk is poured into vats and runs through open channels into tanks, where it remains slightly heated until it has "ripened," that is, until it is slightly clotted.

The oleomargarine, the oil and the ripened milk are run in measured quantities into the churns, of which there are nine. Each churn is a large jacketed pan provided with a steam engine to keep the contents stirred. The ingredients are here completely mixed, and are worked together until they have the appearance of custard. The only resemblance to butter is in the color, which is partly artificial. As is well known, all butter is colored with annatto, and this material is used for margarine. The quantity employed is very small and differs for the various markets in order to suit local tastes. If the liquid margarine were run into moulds and allowed to cool, it would simply form lumps of solidified fat, and be very different from butter. The characteristic of the real product of the dairy is "grain," and care has always to be used not to destroy this by too much rubbing. This grain is obtained with margarine by allowing it to flow in a thin stream, which is met and broken up by a jet of ice-cold water. The fat immediately solidifies in granular form and falls into a tank measuring 20 feet by 12 feet by 2 feet. Here it accumulates on the surface of the water and becomes thoroughly set, looking like an accumulation of pale golden sleet. There are four of these cooling tanks, built in white glazed brick, and situated in a large hall of about an acre in extent, in which the remainder of the operations are conducted.

When the margarine is perfectly set it is skimmed off with wooden shovels, and placed in wooden trucks for two hours to drain. It is then taken to one of four circular working tables, which are not unlike those in use in dairies, but enormously larger. Here it receives its first working, and is salted, and is then removed to another type of machine to be further worked. It is then ready to be made up into rolls and pats, or put into firkins, ready for delivery into the railway trucks. Several qualities are made, but all have a distinct flavor of butter and are pleasant to the taste.

Naturally all these processes demand the employment of a considerable amount of power. There are three Lancashire boilers, 30 feet by 8 feet, by Tinkers, Limited, of Hyde, near Manchester, working at 120 pounds pressure; a Calvert's circulating economizer; two compound condensing engines, with cylinders 15 inches and 28 inches in diameter by 36 inches stroke, with Collman's valve gear, by Messrs. J. Jessop & Son, of Leicester; four ammonia compressors of foreign

make; and four dynamos—three of 50 amperes and 110 volts, and a smaller one for charging batteries—supplied by Messrs. Calvert & Co., of Manchester. The engines, compressors and electric plant are situated in an engine hall, measuring 92 feet by 80 feet and 21 feet high up to the eaves. The floor is tesselated; the walls are of cream-colored glazed brick up to a considerable height, with bands of other colors; the roof is lined with varnished pine boards. We have never seen such a striking machinery room. The effect is, however, somewhat spoiled by the glaring color of paint used for the engines and compressors, but possibly Mr. Monsted chose it to suit the tastes of the vendors of the various varieties of "Dosset," whom he hopes to convert to an appreciation of the good qualities of his margarine.

The ammonia compressors deliver into a refrigerator made of pipes and situated on the roof. This is continually under a stream of water, raised by a centrifugal pump. The cooled ammonia is then conducted into coils of pipe, where it is allowed to expand and take heat from the water by which the coils are surrounded. This water is then used for cooling and crystallizing the margarine. The refrigerators are capable of cooling 240,000 gallons of water per day to freezing point, and are constructed under the patents of Mr. P. Schou. The compressors and the line shafting are all rope driven, and the engines are so arranged that either will drive all the machinery in the place. The condensing water for the engines is artificially cooled by an apparatus that will reduce 24,000 gallons per hour from 140 deg. Fah. to the temperature of the atmosphere. The water is made to trickle down vertical deal boards stacked in the open. There are two tiers of these boards, which are 9 feet by 8 inches by ¾ inch. The upper tier are all set east and west (say) about 2 inches apart, so that a wind from either of these directions will blow through the long lanes formed between the boards. The lower tier are set north and south, and will catch those winds. On the top of all are shallow V-shaped troughs into which the water is delivered, and from which it overflows in streams down both sides of each board. At the bottom of the first tier it is again caught in troughs and again distributed over the second tier of boards, being received at the bottom in a concrete gutter, from whence it runs to the engine room. The total cooling surface is 51,000 square feet, reckoning both sides of the boards. This is quite an original form of condenser, and is found to work well. Its great merit is that it affords abundant surface at small cost. The entire machinery has been laid out with a view to economical working, and bears the impress of skill and thought. Messrs. Bird & Whittenbury, Manchester, were the architects, and Messrs. A. & B. Hanson, Southall, the contractors; Mr. W. McMillan was the clerk of the works.

THE MASK AND FALSE NOSE INDUSTRY.

FOR the last four years the carnival and midlent have had infused into them an extra amount of animation. This renaissance of exoteric merriment coincides with the advent of confetti. Let us leave to philosophers the care of deciding whether the invention of the snow of paper has been a cause or a consequence, in order to examine more particularly what effect the merry making of the carnival has had upon the mask industry. This industry was in a state of utter stagnation. After the war and the disappearance of the fat ox, people (in Paris, at least) had come to completely ignore the charm of painted cardboard faces. Had it not been for the export demand, principally from South America, and the small orders from amateurs of cotillions, manufacturers would simply have had to shut up shop. At present those bad times are almost forgotten; the mask has again come to the front, and this year more have been sold than there were under the empire.

When we say masks, we must explain what we mean. Capital still shows itself recalcitrant to the facial cuirass and admits only the half mask with a chin jointed to it by means of rubber, or, more preferably, the false nose. This happy appendage, when it is well chosen and sufficiently conformable to the style of beauty of the wearer, is quite enough of itself to transform the characteristics of the physiognomy. What good is it, then, to suffocate behind a rampart of cardboard? Such is the opinion of Paris and the departments of the north. But the south belongs to another school. At shrovetide, it intends to preserve its incognito in the most impregnable manner, and to this effect makes use of a great number of full masks. There are, moreover, masks for all tastes and to suit every purse, from those that sell at 65 cents a gross to those at $12 a dozen. These, of course, are wholesale prices. The retailers increase these figures as much as they can, and one could not think of blaming them much, since the article is not of prime necessity, and every one must live.

Do not imagine, however, that, despite the resurrection of the mask, its manufacture constitutes an industry of prime importance whose fluctuations can have a serious reflex effect upon the manual labor of Paris. The number of persons, almost all women, who gain a livelihood at this trade, including the decorators and the false hair workers (for the cardboard heads have special wig workers and hair dressers), is estimated at about a hundred and fifty only. These various artists turn out about one million or one million two hundred thousand masks of a value, say, of $30,000.

Poor artists! they do not earn much; but, fortu-

THE SCULPTOR.

THE MOULDERS.

THE PAINTER

nately for them, the work, which is concentrated in a very small number of houses, only one of which, the Moncharmont establishment, is of genuine importance, is regular from one end of the year to the other and is not subject to stoppages. At the most, it becomes slack in the worst days of winter, when fingers benumbed by cold refuse to handle the sized pulp of which the women always have the hands full. And then, another compensation is that the apprenticeship is short, it taking a somewhat clever apprentice but a week to learn the elements of the trade.

In reality, it is only the creation of the models that requires a part of invention. A sculptor for masks! That is a specialty that would have merited a place in the gallery of odd trades to which we have already devoted a series of studies. But those interested would have protested against this classification. They would have severely recalled to us that a beautiful ugliness forms part of general æsthetics, and that the statuary of the middle ages drew its most intense effects from the hypertrophy of the human passions for the ornamentation of the Gothic cathedrals. They would have sent us to look at the gargoyls of Notre Dame, and we should have returned still more convinced than we are already.

Let us, without irreverence, enter the studio of one of these petrifiers of grimaces. The master is surrounded with figures that give him the prototype of every expression, the la of the simple expressions—fear, surprise, joy, pity, etc. It is impossible to work from nature on account of the self-love of models or of the difficulty that would be experienced in making a living face preserve a fugitive expression during some hours of posing. The sculptor therefore works from memory or imagination. After he has modeled his clay in high relief, he arranges his half head upon a vertical plane and deforms or exaggerates the features according to the inspiration of his fancy. Of this one he draws out the tongue, and of that one he increases the nose to an immeasurable degree. A human face will border upon a resemblance to an animal, while an animal face will fraternize with humanity. The whole object is to find something new, and that is not an easy thing to do. Do you know, in fact, what a gamut of first sketches comprises in a well equipped house? Ten thousand models, at least. Make your selection.

The specialists of whom we speak formerly had a resource upon which they drew largely, and that was the political series. At the close of every year, the sculptor surrounded himself with photographs of persons who, for the last twelve months, had played a role in the popular preoccupations, and first reproducing their features as accurately as possible, made caricatures of them by means of a few well applied strokes of the thumb. The heads of General Boulanger and Henri Rochefort respectively were those that were oftenest put under contribution. But, since a certain time past, the susceptibilities of the police have been awakened, and the political series has had to disappear, at least from the catalogues.

After the models are finished, a certain number of hollow moulds are made from them and delivered to the women operatives.

Each of these latter has in front of her a large number of different models, generally a gross, of which the difficulty is varied so that the task may be equitably distributed among all. In fact, as the work is always paid for by the piece, it is important that certain privileged ones shall not monopolize the simple moulds and thus be allowed to double their pay to the detriment of their less favored comrades.

The distribution having been made by the forewoman, our operatives are ready for business. Alongside of them there is a pile of sheets of cardboard whose thickness varies according to the quality of the object to be obtained, but all water soaked and absolutely soft. As the sheet offers no resistance, it readily adapts itself to all the sinuosities of the mould. On the contrary, it tears very easily, and it is necessary to repair the holes and fissures with pieces dexterously laid and fixed with glue—little cardboard plasters that must not show upon the dried mask.

In measure as the work proceeds, the operative places her moulds upon open frames, quite similar, except as to dimensions, to the bottle racks of our wine cellars. At the end of a few hours the mask is sufficiently dry to be taken from the mould. If need be, its desiccation is hastened by placing it in a stove.

The average production varies between twelve and eighteen masks an hour, and the hours of daily work are ten. The labor, as may be seen, is quite monotonous, and it becomes still more so by the fact of the specialization in such or such a part of the trade in order to increase the rapidity of execution. Thus, as regards false noses and half heads, one woman, from one end of the year to the other, will make snub noses or galosh chins. This permits of long incidental reveries.

But here are our masks accumulated in a pile. Every afternoon, other operatives come to get a load of them. The varnishers, in fact, work at home in most cases. Two or three brushes and a few pots of elementary colors comprise their entire outfit, and as they are not painting miniatures, the daubing of the noses proceeds quickly.

It only remains to send the choice pieces to the capillary artists, who give the last finishing touches. Here ends the genesis of the mask properly so called.

FIG. 3.—GERMAN ALMANAC OF 1818, FRENCH ALMANAC OF 1819, AND ENGRAVING FROM A BOOK PUBLISHED IN 1802.

The rarer and costlier models that require frames of iron or mechanical combinations enter into the specialty of theater articles and are fashioned by other manufacturers. However, it is in the false nose shops that may be procured those false faces that are so useful at certain dinners and evening parties.

To this effect, the person invited, having fixed his choice upon such or such an illustrious resemblance, visits our manufacturer, and, after looking over his ten thousand models, points out to him those that contain the details of the face desired. One borrows the nose of this one, the mouth of that one, and the ear of another, and from these separate elements is formed the celebrated portrait. The mask is therefore made also according to measurement.—Le Monde Illustré.

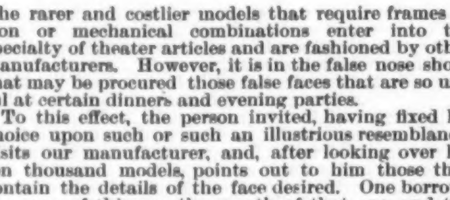


FIG. 5.—THE SMALLEST BOOK KNOWN. (ACTUAL SIZE.)

THE SMALLEST BOOK KNOWN.

As a sequel to our article on minute books, we desire to call attention to a rarity in this line, but, before doing so, shall mention the titles of a few more that are found in our library and in that of Mr. George Salomon.

The bindings of these Liliputian works is in nowise inferior to those of books of ordinary size. In Fig. 1 we have grouped representations of six minute books of which the titles are as follows: Les Petits Montaguards (1822); Le Tableau de la Vie (1821); Valeur et Constance (1823); Etrennes Nationales à l'Usage des Dames Patriotes (1798); Le Petit Fabuliste; Les Ris, les Jeux, les Plaisirs (1818).

If the bindings of these little books are charming, the engravings that they contain are no less so. In Fig. 2 we give specimens of engraved vignettes selected from six different booklets: Etrennes Mignonnes pour l'Année 1818; Le Conseiller des Grâces, dedié aux Dames (1817); Etrennes aux Grâces ou les Proverbes de Cythere (1819); Les Oreilles (title wanting); Petit Paroissien de l'Enfance; Poete de l'Enfance.

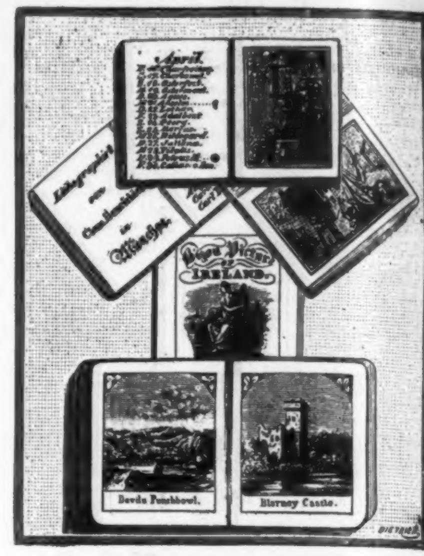


FIG. 4.—GERMAN ALMANAC OF 1827, WITH LITHOGRAPHS OF SENEFELDER AND ALBUM OF VIEWS IN IRELAND.

Fig. 3 continues the reproduction of engravings extracted from small almanacs, and which we figure as we find them opposite their text. The book at the upper part of this figure represents a minute almanac of 1818. It is entitled Almanach auf das Jahr, and its pages are no more than six-tenths of an inch in length. This wonderful booklet contains 12 engravings and is inclosed in a case that we reproduce in the center of the engraving. Beneath this case we give a facsimile of a page of another almanac entitled Le Joujou Amusant, Almanach Nouveau pour l'Année 1802. To the right of this elegant little almanac may be seen a charming image of a lady artist, which is found in Le Petit Volage for 1819.

Small books were sometimes the work of great artists. Fig. 4 gives a reproduction of two pieces of extreme interest. At the top of the figure we see an open German almanac of 1827. It is illustrated with minute lithographs executed by C. Senefelder, the inventor of lithography. We reproduce the inscription engraved at the head of the book with a page and two lithographs that accompany it.

Beneath the Senefelder almanac we show an exquisite English album entitled Bijou Picture of Ireland, and illustrated with 30 engravings of Irish landscapes and edifices. Two specimens of the very remarkable engravings of this album are faithfully reproduced at the bottom of Fig. 4.

The minute books under consideration do not treat solely of amusing and frivolous things, for they include Bibles and prayer books. We find among them the Testaments of Louis XVI. and Marie Antoinette, L'Exercice du Chretien, Le Bonheur de la Paix (1763), and La Belle Humanité (1764), a German work containing the portraits and biographies of great men. Certain of these little books seem to come from fairy hands. In mentioning those that are found in the unique collection of Mr. Salomon and in our own, we gave, as the smallest books known, a Chemin de la Croix and a Livre de Prieres, French works, whose justification, that is to say, the length and width of the page of impression, measures 0·5 × 0·21 inch. But we find that a smaller one still has been published in Holland. Its dimensions are so small that it is not surprising, despite its antiquity, that it has escaped all investigations.

The page of impression measures but 0·39 × 0·21 inch,

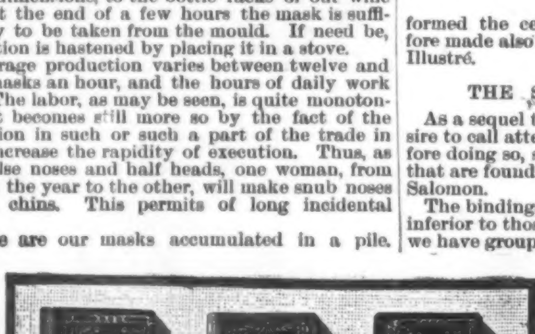


FIG. 1.—SPECIMENS OF BINDINGS OF SMALL BOOKS. (ACTUAL SIZE.)

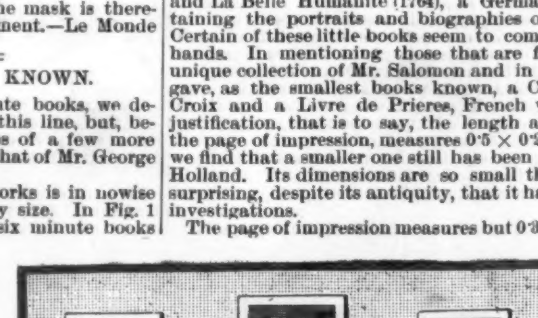


FIG. 2.—SPECIMENS OF ILLUSTRATIONS OF SMALL BOOKS. (ACTUAL SIZE.)

and the entire page, impression and margin, 0·66 × 0·81 inch. It contains 49 pages. The title is Bloem Hofje door C. van L., Gedruckt by B. Schmidt. On the last page is the date 1674. It is elegantly bound in antique calf with ornate back and sides and gilt edges, and is provided with a clasp of gold filigree work of exquisite delicacy. In a word, this dwarf of dwarfs offers wholly the aspect of a large well conditioned volume. It would require four like it to cover one of our postage stamps, Fig. 5.—From La Nature.

THE RECOVERY OF DIAMONDS FROM DIAMONDIFEROUS EARTH.

THE story of Kimberley has often been told since the diamond mines were first discovered in 1870, when men bought claims at ten shillings, subsequently selling them for £10,000 to £15,000 each to purchasers who have done equally well. A truly charming record of these events is that given in "Diamonds and Gold in South Africa," a work by Mr. Theodore Reunert, and published by Edward Stanford, Cockspur Street, London; so that the title of this article is suggested not by a desire to deal with the general question, but rather with the view of referring to a new process for the recovery of diamonds. In Mr. Reunert's book the method hitherto adopted in most part is fully described, and an extract may make the purpose of the new plant more obvious. The diamondiferous earth is raised from the Kimberley mines by powerful hoisting machines, skips holding six loads of blue ground being raised 1,000 ft. in forty-five seconds. Arrived at the surface, the skips are tipped automatically into ore bins, from which the blue ground is filled into steel side-tipping trucks of twenty cubic feet capacity, and conveyed to the depositing floors by an endless chain haulage driven by an independent steam engine. The tramways are all eighteen inch gage, and on the floors light locomotives are used for taking the trucks to and from the terminus of the mechanical haulage. There is a slight grade from the mine to the floors, which materially assists the loaded trucks on the down line bringing up the empties.

On the floors of De Beers mine a more elaborate system of endless wire rope haulage is employed several miles in length. The length of the main haulage is three miles, with two branches one mile and three-quarters of a mile in length respectively. The floors commence about a mile from the mine, and extend for three miles in an easterly direction and a mile in a westerly direction. Besides the main haulage lines, there are two in use taking blue up the inclines at the washing machines, each about one-half mile long. The speed of the haulages varies from two and one-half to four miles per hour.

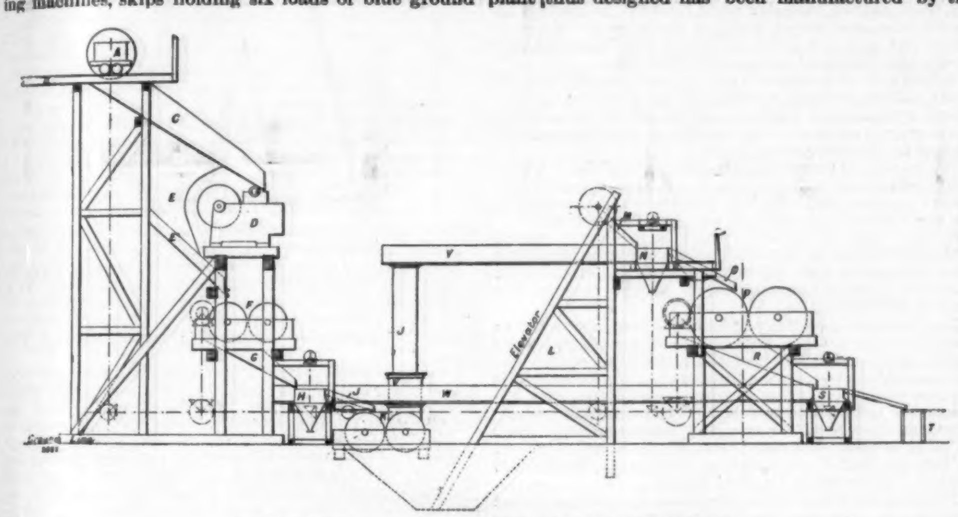
The depositing floors are made by removing the bush and grass from a fairly level piece of ground. The land is then rolled and made as hard and smooth as possible. The De Beers floors on Kenilworth (a farm of some 17,000 acres, belonging to the company) are laid off in rectangular sections, 600 yards long and 200 yards wide. Each section holds about 50,000 loads. The depositing is done by horses on portable tram lines extending at right angles from the main lines on either side of the floors. A load of blue ground (sixteen cubic feet) weighs about 1,600 lb., and covers about twenty-one square feet when deposited on the floors. For a time the blue ground remains on the floors without much manipulation. The heat of the sun and moisture soon have a wonderful effect upon it. Large pieces, which were as hard as ordinary sandstone when taken from the mine, soon commence to crumble. At this stage of the work the winning of the diamonds assumes more the nature of farming than mining. The ground is continually harrowed to assist pulverization, by exposing the larger pieces to the action of the sun. Spans of mules were formerly used for drawing the harrow to and fro, but steam traction engines with gear for drawing the harrows, on Fowler's well-known steam plowing system, are now employed at both Kimberley and De Beers.

The length of time necessary for the ground to be exposed before it becomes sufficiently pulverized for washing depends on the season of the year and the amount of rain. The blue ground of the four mines differs as to the length of time necessary for pulverization. The blue from Kimberley mine becomes quite well pulverized in three months during the summer (the rainy season), while that from De Beers requires double that time. The longer the ground remains exposed, the better it is for washing. Some of the De Beers ground is so hard that it has to be broken in a fine crusher before it can be washed.

The disadvantages of the system will be obvious, and Mr. T. G. McLelland, the general manager of the New Gordon Diamond Company, Limited, Kimberley, has designed machinery to supersede the farm method of pulverizing the diamondiferous earth, so that a day or two, instead of several months, will suffice to show whether the earth contains diamonds. The plant thus designed has been manufactured by the Chatteris Engineering Works Company, Chatteris, Cambridgeshire, and is about to be exported. The accompanying engraving shows the general arrangement. Instead of being sent to the farm, the blue ground is raised to a gantry about thirty-eight feet above ground level, as shown by B. The contents of the truck are tipped down the grizzlies, C, the small stuff the while dropping through to the shoot, E, and E', which is fitted with a fan feeder, while the heavier blue ground passes into the crusher, D, being subsequently assisted by the fan into the shoot, E'. All the material thus passes into the pair of rolls, F, where the process of pulverization is furthered.

Thereafter the material is sent through a series of pulsators, the plungers of which work at a high speed. The first series of four is marked H. The heavy stuff descends through the sieves, and is carried away by a spiral elevator; the light stuff is washed over the top and led by screen shoots, J, to the second or intermediate rolls, K, which are constructed to crush slightly smaller than the first. After the second crushing the blue ground is lifted by elevator, L, and discharged by a shoot into a second series of four pulsators, N. Here, as at the first pulsators, arrangements are made for draining away the water and fine mud to the settling tank. From the second pulsators the stuff descends by shoots again to a third pair of rolls, P, after which the ground is pulsated in six boxes, S, the launder, T, being for the tailings. The gearing throughout is of cast steel, so as to reduce weight. A high-level centrifugal pump is used, in addition to a low-level pump at V, launders for conveying water for the pumps and pulsators being shown by Y and W.

Two sets, as illustrated, have been constructed, each to deal with 1,000 loads, or 2,000 loads altogether, per day, the advantage of duplication being obvious as a prevention against complete breakdown. A wash-up machine is included in the installation. In it there are five pulsators, and at the foot of each box is a closed-in elevator, lifting the deposit clear of the water level and discharging into locked-up boxes. The water and slum passing over the pulsator is caught in a launder, running in front of the boxes, and the water is lifted again to the level of the pulsators by means of a scoop wheel, while the slum is drawn off in a similar manner as described for the main launder. With regard to the cost of working the complete installation, it is claimed that when it is in operation the expenses of pulverization will be reduced from the present rate of from 10s. to 12s. per load to about 4s. 3d.—Engineering.



DIAMOND WASHING MACHINERY.

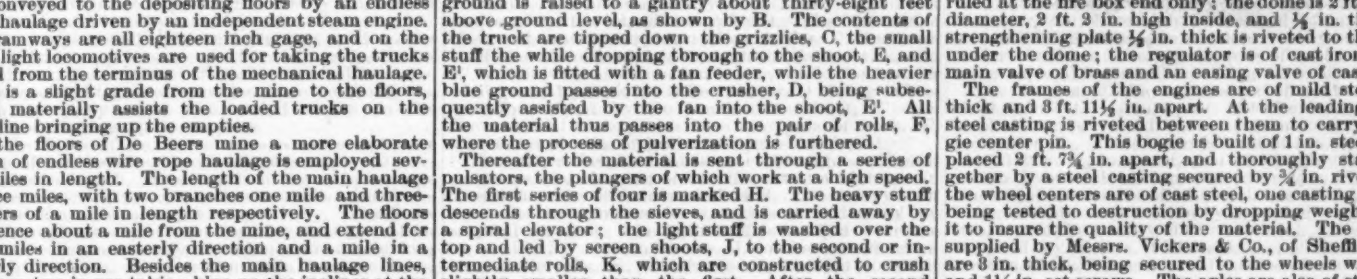
FOUR-COUPLED BOGIE ENGINE, LONDON AND SOUTHWESTERN RAILWAY.

WE illustrate from the Engineer, London, one of twenty engines now at work. The first was turned out in June, 1890. The engine has four-coupled driving wheels 7 ft. 1 in. in diameter, while the front of the engine is carried on a four-wheeled bogie, having wheels 3 ft. $9\frac{3}{4}$ in. in diameter. The cylinders are 19 in. in diameter by 26 in. stroke, and the tractive effort developed is accordingly 110·42 lb. for every pound of mean effective steam pressure in the cylinders. The cut-off varies from 75 per cent. in full gear to 17 per cent. in the usual running conditions. The boiler pressure is 175 lb. per square inch, and hence the total tractive effort available is about 18,000 lb. at starting and 8,000 lb. in the running conditions. The total weight on the coupled drivers is 30 tons 6 cwt., which, with a coefficient of adhesion of one-fourth with sand blast, is ample to prevent slipping at starting.

The boiler is necessarily made large to give a sufficient supply of steam for such large cylinder capacity, while keeping down the rate of evaporation per square foot of heating surface and of firegrate. It is constructed entirely of mild steel, free from silicon, sulphur, and phosphorus, and having a tensile strength of not less than twenty-five tons nor more than thirty tons per square inch, with an extension of 23 per cent. in 10 in. The boiler barrel is 11 ft. long between tube plates, and 4 ft. 4 in. in diameter, and is built of $\frac{5}{8}$ in. plates. The longitudinal joints have inner and outer cover strips, with zigzag double riveting. The transverse joints are made with an external weldless butt ring, double riveted. This ring is turned to gage and shrunk on. The smoke box tube plate is $\frac{3}{4}$ in. thick and is flanged for the smoke box. It is secured to the barrel of the boiler by a weldless steel angle ring turned to gage. The external fire box is 6 ft. 4 in. long by 3 ft. $10\frac{1}{2}$ in. wide, and the bottom extends 5 ft. below the center line of the boiler. The top and side plates are $\frac{5}{8}$ in. thick, and the front and back plates $\frac{9}{16}$ in. The rivets are all $\frac{7}{8}$ in. in diameter, and are of the best Yorkshire iron. The internal box is of copper and measures 5 ft. $6\frac{1}{16}$ in. long at the top and 5 ft. $7\frac{7}{8}$ in. long at the bottom, inside measurements. Its height inside at the center is 5 ft. $9\frac{1}{2}$ in., and the width inside at the top is 3 ft. 6 in. and at the bottom 3 ft. $2\frac{1}{2}$ in. The tube plate is $\frac{7}{8}$ in. thick where the tubes pass through it and $\frac{1}{2}$ in. elsewhere. Two fusible plugs are fitted in the crown of the box; the fire box contains a brick arch; the fire bars are of cast iron; the tubes, which are of brass, are 240 in number, $1\frac{3}{4}$ in. outside diameter, tapered inside, they are ferruled at the fire box end only; the dome is 2 ft. outside diameter, 2 ft. 3 in. high inside, and $\frac{1}{2}$ in. thick. A strengthening plate $\frac{1}{2}$ in. thick is riveted to the boiler under the dome; the regulator is of cast iron, with a main valve of brass and an easing valve of cast iron.

The frames of the engines are of mild steel, 1 in. thick and 3 ft. $11\frac{1}{2}$ in. apart. At the leading end a steel casting is riveted between them to carry the bogie center pin. This bogie is built of 1 in. steel plates placed 2 ft. $7\frac{3}{4}$ in. apart, and thoroughly stayed together by a steel casting secured by $\frac{3}{4}$ in. rivets. All the wheel centers are of cast steel, one casting in forty being tested to destruction by dropping weights on to it to insure the quality of the material. The tires are supplied by Messrs. Vickers & Co., of Sheffield, and are 3 in. thick, being secured to the wheels with a lip and $1\frac{1}{2}$ in. set screws. The axles are also of steel, with a tensile strength of not less than 28 tons nor more than 32 tons per square inch, and an elongation of not less than 25 per cent. in 2 in. As an additional precaution a piece $1\frac{1}{4}$ in. square has to stand a test of being bent double while cold without showing any signs of failure. The bearings for the driving axles are 8 in. in diameter by 9 in. long. A compensating beam is provided between the driving and trailing axles.

As already mentioned, the cylinders are 19 in. in diameter by 26 in. stroke. The steam ports are 16 in. long by $1\frac{1}{2}$ in. wide, the exhaust port being 3 in. wide. The bars between the ports are $1\frac{1}{2}$ in. wide. The cylinders are fixed to the frames, with $1\frac{1}{4}$ in. turned bolts. The steam chests are carried through the frames as usual with outside cylinder engines in this country. The slide valves are of Stone's bronze, with recesses on the working faces. The pistons are of cast steel, and are packed with three cast iron rings, $\frac{5}{8}$ in. wide by $\frac{1}{2}$



EXPRESS PASSENGER ENGINE, LONDON AND SOUTHWESTERN RAILWAY.

in. thick. The piston rods are carried through both covers, and are 3⅝ in. in diameter at the crank end and 2¼ in. at the other. They are made of steel and are packed with "United States" metallic packing. The valve buckles and spindles are of Yorkshire iron case-hardened. The crossheads are of cast steel, with cast iron rubbing pieces, which are secured to the crossheads by ⅝ in. turned bolts. The valve motion is of the curved link type, the links being suspended from their centers. The eccentric sheaves are made in two parts, and have a throw of 6 in. The straps are of cast iron. The reversing motion is fitted with a screw gear, and is on the right hand side of the engine. The reversing shaft is of Yorkshire iron, with the levers forged solid with the shaft, all working parts of the shaft being case-hardened. The connecting rods are of Yorkshire iron, and measure 6 ft. 8 in. from center of crosshead pin to center of crank pin. They have adjustable brasses at the large end and gun metal bushes forced into place by hydraulic pressure at the crosshead end. The coupling rods are also of Yorkshire iron, but they are machined to an H section, and are fitted with plain gun metal bushes at the ends. These bushes are, however, lined with white metal strips. The crank pins are of Yorkshire iron, case-hardened, and are forced into their places in the wheels by hydraulic pressure and riveted over on the inside.

The engines are fitted with Adams' patent vortex blast pipe, which is claimed to give a very even draught and a soft exhaust. The engines are fitted with a steam and an automatic vacuum brake; the brake blocks are of cast iron. Two injectors are fixed one on each side of the engine (Dewrance's pattern).

The tender attached to the engine is carried on six wheels, 3 ft. 9¾ in. in diameter, with a wheel base of 13 ft. The bearings for the axles are 5¼ in. in diameter and 9 in. long, and are outside the wheels.

The frames are double, the outer plates being ⅞ in. and the inner ones ½ in. thick respectively. The tender is designed to carry 3,300 gallons of water and three tons of coal.

The principal dimensions of the engine and tender are as follows:

ENGINE.

	Ft.	In.
Inside diameter of cylinders	1	7
Stroke of piston	2	2
Length of boiler barrel between plates	11	0
Diameter of boiler barrel outside	4	4
Length of fire box shell outside	6	4
Heating surface:		
Tubes	1245·6 sq. ft.	
Fire-box	122·16 "	
Total	1367·76 sq. ft.	
Grate area	18 sq. ft.	
	Ft.	In.
Width of fire box shell at bottom	3	10½
Number of tubes—240		
Diameter of tubes outside	0	1¾
Height of center of boiler from rail	7	9
Length of engine frame	30	4
Thickness of engine frame	0	1
Distance between frames	3	11½
Diameter of bogie wheels on tread	3	9¾
Diameter of driving and trailing wheels on tread	7	1
Center of bogie to center of driving axle	10	9
Center of driving to center of trailing wheels	8	6
Center to center of bogie wheels	7	6
Wheel base from center of leading bogie to center of trailing wheels	22	0
Height of center of buffers from rails	3	6
Working steam pressure	175 lb. per sq. in.	
Weight of engine (in working order):		
On bogie	18 tons 7 cwt. 2 qr.	
On driving wheels	15 tons 9 cwt. 0 qr.	
On trailing wheels	14 tons 17 cwt. 0 qr.	
Total	48 tons 13 cwt. 2 qr.	

TENDER.

	Ft.	In.
Diameter of wheels on tread	3	9¾
Center to center of wheels	6	6
Length of journal	0	9
Diameter of journal	0	5¼
Diameter of axle in wheel	0	6⅝
Diameter of axle at center	0	6⅛
Wheel base	13	0
Length of frame	19	9½
Total length of wheel base from center of leading bogie wheels of engine to center of hind wheels of tender	44	3½
Length over all, from front buffers of engine to hind buffers of tender	53	8⅝
Height of center of buffers from rails	3	6
Capacity of tank	3,300 gallons	
Weight of tender (in working order):		
On front wheels	10 tons 19 cwt. 2 qr.	
On center wheels	10 tons 12 cwt. 2 qr.	
On hind wheels	11 tons 19 cwt. 0 qr.	
Total	33 tons 4 cwt. 0 qr.	
Total weight of engine and tender in working order	81 tons 17 cwt. 2 qr.	

These engines have been designed for the fast express passenger traffic of the London and Southwestern Railway Company, and have given excellent results. The kind of work done is well shown by the profiles of the line. The distance from Waterloo to Southampton West is run without a stop at a speed of 47·55 miles per hour. The return journey to Vauxhall, 78 miles, is done still more quickly, the speed being 50 miles an hour. In this run long gradients have to be surmounted. Another good run is that from Waterloo to Christchurch, a distance of 104 miles, which is run without a stop at the rate of 46 miles an hour. Still more trying runs, perhaps, are those from Waterloo to Basingstoke, and from that place on to Salisbury, Crewkerne and Exeter. The distance from Waterloo to Salisbury, 83¾ miles, is run at a speed of 45·5 miles per hour. From this point on to Exeter some very heavy gradients are met with, there being many stretches of 1 in 80 to be surmounted, as well as half a mile of 1 in 70. To keep time over such a trying road requires powerful engines, especially as the train load on these fast runs often amounts to 310 tons, engine and tender included. This load is made up of ten six-wheeled vehicles of 15 tons each, four bogie coaches of 20 tons each, and the engine and tender. The net train load is therefore 230 tons.

THE UNITED STATES UNITS OF ELECTRICAL MEASURE.

By a law approved in the Senate of the United States last July, it was enacted that the legal units of electrical measure in the United States should be as follows:

(1) The unit of resistance shall be what is known as the international ohm, which is substantially equal to one thousand million units of resistance of the centimeter-gramme-second system of electromagnetic units, and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice fourteen and four thousand five hundred and twenty-one ten-thousandths grammes in mass, of a constant cross sectional area, and of the length of one hundred and six and three-tenths centimeters.

(2) The unit of current shall be what is known as the international ampere, which is one-tenth of the unit of current of the centimeter-gramme-second system of electromagnetic units, and is the practical equivalent of the unvarying current, which, when passed through a solution of nitrate of silver in water in accordance with standard specifications, deposits silver at the rate of one thousand one hundred and eighteen millionths of a gramme per second.

(3) The unit of electromotive force shall be what is known as the international volt, which is the electromotive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of an international ampere, and is practically equivalent to one thousand fourteen hundred and thirty-fourths of the electromotive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of fifteen degrees Centigrade, and prepared in the manner described in the standard specifications.

(4) The unit of quantity shall be what is known as the international coulomb, which is the quantity of electricity transferred by a current of one international ampere in one second.

(5) The unit of capacity shall be what is known as the international farad, which is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity.

(6) The unit of work shall be the joule, which is equal to ten million units of work in the centimeter-gramme-second system, and which is practically equivalent to the energy expended in one second by an international ampere in an international ohm.

(7) The unit of power shall be the watt, which is equal to ten million units of power in the centimeter-gramme-second system, and which is practically equivalent to the work done at the rate of one joule per second.

(8) The unit of induction shall be the henry, which is the induction in a circuit when the electromotive force induced in this circuit is one international volt, while the inducing current varies at the rate of one ampere per second.

The National Academy of Sciences was instructed to prescribe and publish the specifications necessary for the practical application of the definitions of the ampere and volt given in the foregoing, and, to meet this requirement of Congress, a special committee was appointed to consider the subject. The committee, selected from members of the academy, was as follows: Prof. H. A. Rowland, chairman; Gen. H. L. Abbot, Prof. G. F. Barker, Prof. C. S. Hastings, Prof. A. A. Michelson, Prof. J. Trowbridge, Dr. Carl Barus.

The report of this committee was submitted to the academy at a special meeting held recently, and was then accepted and unanimously adopted. We extract the following details from the report, a copy of which has just reached us:

THE AMPERE.

In employing the silver voltameter to measure currents of about one ampere, the following arrangements shall be adopted:

The kathode on which the silver is to be deposited shall take the form of a platinum bowl not less than 10 centimeters in diameter, and from 4 to 5 centimeters in depth.

The anode shall be a disk or plate of pure silver some 30 square centimeters in area and 2 or 3 millimeters in thickness.

This shall be supported horizontally in the liquid near the top of the solution by a silver rod riveted through its center. To prevent the disintegrated silver which is formed on the anode from falling upon the kathode, the anode shall be wrapped around with pure filter paper, secured at the back by suitable folding.

The liquid shall consist of a neutral solution of pure silver nitrate, containing about 15 parts by weight of the nitrate to 85 parts of water.

The resistance of the voltameter changes somewhat as the current passes. To prevent these changes having too great an effect on the current, some resistance besides that of the voltameter should be inserted in the circuit. The total metallic resistance of the circuit should not be less than 10 ohms.

Method of Making a Measurement.—The platinum bowl is to be washed consecutively with nitric acid, distilled water and absolute alcohol; it is then to be dried at 160° C., and left to cool in a desiccator. When thoroughly cool it is to be weighed carefully.

It is to be nearly filled with the solution and connected to the rest of the circuit by being placed on a clean insulated copper support to which a binding screw is attached.

The anode is then to be immersed in the solution so as to be well covered by it and supported in that position; the connections to the rest of the circuit are then to be made.

Contact is to be made at the key, noting the time. The current is to be allowed to pass for not less than half an hour, and the time of breaking contact observed.

The solution is now to be removed from the bowl, and the deposit washed with distilled water, and left to soak for at least six hours. It is then to be rinsed successively with distilled water and absolute alcohol, and dried in a hot air bath at a temperature of about 160° C. After cooling in a desiccator it is to be weighed again. The gain in mass gives the silver deposited.

To find the time average of the current in amperes, this mass, expressed in grammes, must be divided by the number of seconds during which the current has passed, and by 0·001118.

In determining the constant of an instrument by this method the current should be kept as nearly uniform as possible, and the readings of the instrument observed at frequent intervals of time. These observations give a curve from which the reading corresponding to the mean current (time average of the current) can be found. The current, as calculated from the voltameter results, corresponds to this reading.

The current used in this experiment must be obtained from a battery and not from a dynamo, especially when the instrument to be calibrated is an electrodynamometer.

THE VOLT.

Definition and Properties of the Cell.—The cell has for its positive electrode, mercury, and for its negative electrode, amalgamated zinc; the electrolyte consists of a saturated solution of zinc sulphate and mercurous sulphate. The electromotive force is 1·434 volts at 15° C., and between 10° C. and 25° C., by the increase of 1° C. in temperature, the electromotive force decreases by 0·00115 of a volt.

To Set Up the Cell.—The containing glass vessel, represented in the accompanying figure, shall consist

of two limbs closed at bottom and joined above to a common neck fitted with a ground glass stopper.

The diameter of the limbs should be at least 2 centimeters and their length at least 3 centimeters. The neck should be not less than 1·5 centimeters in diameter. At the bottom of each limb a platinum wire of about 0·4 millimeter diameter is sealed through the glass.

To set up a cell, place in one limb pure mercury and in the other hot liquid amalgam, containing 90 parts mercury and 10 parts zinc. The platinum wires at the bottom must be completely covered by the mercury and the amalgam respectively. On the mercury, place a layer one centimeter thick of the zinc and mercurous sulphate paste, described in 5. Both this paste and the zinc amalgam must then be covered with a layer of the neutral zinc sulphate crystals one centimeter thick. The whole vessel must then be filled with the saturated zinc sulphate solution, and the stopper inserted so that it shall just touch it, leaving, however, a small bubble to guard against breakage when the temperature rises.

Before finally inserting the glass stopper, it is to be brushed round its upper edge with a strong alcoholic solution of shellac, and pressed firmly in place.

THE MAGNETIC NEEDLE.

By VAUGHAN CORNISH, M.Sc., F.C.S.

If we may consider any body which has the property of attracting iron as being a magnet, then the earth itself must be looked upon as the primitive magnet. Iron is not necessarily a magnet, but every piece of iron has a tendency to become one under the inductive action of the earth's magnetic force. If a piece of soft iron be placed in a vertical position, its lower end becomes, in these latitudes, a north-seeking magnetic pole, and by hammering the bar while in this position it becomes a permanent magnet. An iron ship in course of building is subjected to constant hammering, and when it leaves the stocks is a powerful and permanent magnet. Native iron is very rarely met with, but an oxide of iron called loadstone, containing seventy per cent. of the metal, occurs abundantly, and may in a certain sense be considered as the primitive magnet.

With the exception of steel and iron, some of the iron ores, and the allied metals cobalt and nickel, all other bodies are practically non-magnetic; their magnetic properties being almost infinitesimal in comparison with those of iron. This circumstance gives a peculiar character to the science of magnetism, and makes the study of the subject very different from that of electricity, which is associated with all sorts of materials. Another striking difference between magnetism and statical electricity consists in the fact that we cannot isolate "north" magnetism from "south" magnetism, as we do positive from negative electricity. When an iron or steel bar is magnetized, positive and negative magnetism are produced in equal strength and the magnet has its north and south poles. We cannot draw off the "south" magnetism and leave a "north" magnet. The experiment may readily be tried on a watch spring which has been magnetized, after having been heated to redness and cooled suddenly. The watch spring can now be easily broken, and each piece is found to have its north and south end after every occasion of breaking the spring. The north and south ends may be tested by bringing them near to the end of a light and delicately suspended magnet, which readily moves if attracted or repelled. Since the north and south poles of a magnet act in opposite ways and are always of equal strength, it is evident that the further apart the poles of a magnet are the more likelihood there is of obtaining definite and simple effects, such as can readily be understood. The use of the common horseshoe magnet is apt to confuse the tyro, although convenient when the object is to attract powerfully a piece of unmagnetized iron, which is attracted both by the north and by the south pole. Hence the convenience of the horseshoe form, e. g., for setting the index of a registering thermometer. A "keeper" of soft iron which prevents leakage of magnetism is also more conveniently employed with the horseshoe form, but for

those who wish to study the elementary phenomena of magnetism, the bar magnet is much better. In a sewing needle, for instance, the mass of metal being small, the magnetic charge is necessarily small also, and the poles are fairly well out of each other's way.

Some of the simpler magnetic phenomena may be very conveniently observed with the aid of a sewing needle, which is laid gently on the surface of still water after having been magnetized by being drawn across the pole of a magnet. The first thing noticeable is that the needle generally twists about its middle point, after the hand has left it free, and then rests in its new position. If a second magnetized needle be placed in another basin, it will be seen that both needles point in the same direction. They both lie in a northerly direction, known as the magnetic meridian. The effects above described, due to the earth's magnetic force, are different from those produced by bringing the pole of a bar magnet near the floating needle. In that case the needle not only turns to the magnet but follows it, whereas the earth's magnetism gives the needle a twist but no pull. If there were such a pull, the needle would readily show it, for the resistance of the water is less to a motion lengthwise than to the turning of the needle about its middle point. It has been said that the earth acts somewhat as if there were a great bar magnet about half the length of the earth's axis buried inside it, and making a small angle with the axis of the earth's rotation. Although such an analogy is a very rough one and will not stand being pushed very far, nevertheless it represents the facts sufficiently well to be employed as a means of explaining the general character of these elementary phenomena. It is evident that the pole of such a magnet, which is by hypothesis situated at a great distance, could only exercise a twisting, not a pulling force on a magnetized needle. The two poles of the needle being practically at the same distance from the pole of the great magnet, the attraction and repulsion on the north and the south poles of the magnet respectively will be equal in amount. A push at one end of the needle and an equally strong pull at the other cannot drag the needle along, but if the needle be set across the line of force, the push and the pull will act together so as to twist the needle into the direction of the line of force, the magnetic meridian.

In the same way the magnetized needles attached to the under side of the card of a ship's compass keep the card always in the same position, so that as the ship's head turns, the binnacle or compass box revolves round the stationary card, and the "lubber" line marks the point of the compass toward which the ship's head is turned. The card to which the compass needles are attached has in its center a brass socket, with a piece of agate at the bottom, which is supported by an upright pin. A slight amount of friction is all that opposes the tendency of the needle to keep in the magnetic meridian during the turnings of the ship's course. This arrangement does not show, however, whether the earth's directing magnetic force is horizontal or not. The needle and card are free to turn horizontally, but a downward or upward twist, unless very powerful, would expend itself without visible effect against the rigid parts of the apparatus. In the same way, with the sewing needle floating on water, the repulsion between the greasy surface of the needle and the water surface is sufficient to resist the downward pull of gravity, and would prevent us from observing a vertical twist, unless it were a powerful one. To show the true line of action of the earth's directing force upon a magnet, we must use "a needle" mounted on a horizontal axis and free, except for the earth's magnetic action, to turn in a vertical plane. The form of needle used for showing the magnetic dip is the long lozenge shape. If the dip needle be placed so that a line joining the supports be in the magnetic meridian, the needle hangs vertically, and, if the apparatus be gradually turned round, the lower end of the needle tends to rise until, when the needle is in the magnetic meridian, the dip, or angle which it makes with the horizon, is in these latitudes about 67°. Thus in England the line of the earth's magnetic force slopes steeply downward in a northerly direction. The point or points toward which magnetic needles turn are not the "magnetic poles" of the geographer: those are positions on the earth's surface where the dipping needle points vertically downward. The direction in which such a needle points would meet the direction in which, say, a Greenwich needle points at some two thousand miles down in the bowels of the earth. This shows that the centers of the earth's magnetic action are deep seated. The term magnetic poles for places on the earth's surface is perhaps somewhat misleading. These positions are not poles in the sense in which the term pole is used in connection with a bar magnet or a magnetic needle. In these cases we mean positions near the ends, where there is greatest concentration of magnetic strength, centers of force in the magnet. The dip of 67° in these latitudes shows, as has been said, that the centers of magnetic force in the earth are deep seated. If there be "poles" comparable to those of the poles of a bar magnet, they must be even further from the surface of the earth than the point at which the direction of the Greenwich dipping needle meets the direction of the needle where the dip is 90°.

The strength of the earth's magnetic force has been measured in the same way as other forces, in terms of the weight exercised by a given mass under the action of gravity. The determination of the earth's magnetic force requires two principal sets of observations. In the first the earth's action upon a magnetic needle is opposed to the strength of a bar magnet. We find in this way how many times stronger is the action of the magnet on the needle than is the earth's action. If we call H the force exerted by the earth (so much of it at least as comes into play in a horizontal direction) and M the strength of the magnet, then our experiment determines the numerical value of $\frac{M}{H}$. In the second series of observations, we allow the earth's magnetism to act with and reinforce the strength of the magnet, and we determine the value of the two forces acting together and reinforcing one another. Our numerical result is now in the form of a product, viz., the strength of magnet multiplied by the horizontal component of the earth's magnetic force, or $M \times H$. The method employed is to suspend the same bar magnet as that used in the last experiment by a fine wire or thread. The magnet is placed in a stirrup, and the axis is horizontal. Matters are arranged so that when the fiber is without torsion the magnet lies in the magnetic meridian. The magnet is then twisted round its point of suspension, twisting the wire at the same time. Letting go the magnet, we observe the rate of oscillation as the fiber twists and untwists. The rate of oscillation is quicker than that of an unmagnetized bar under the same conditions, for the magnetic force acting between the earth and the poles of the magnet assists the elasticity of the wire to overcome the inertia of the iron bar. This acceleration of the oscillation gives the value of $M \times H$. In the former experiment we determined $\frac{M}{H}$. The value of H can now be calculated, since if we divide the value M H (obtained when earth and magnet force act together) by $\frac{M}{H}$ (obtained when the earth acts against the magnet), the quotient is the square of H. As we know the angle which the line of action of the earth's force makes with the horizon (from the dip observation), we can readily calculate the total magnetic force of which H is the horizontal component. In some observations made in the north of England the dip was 67½°. Hence the total force would be about twice the horizontal component. In experiments in the same locality of which we have the data before us it was found that H was 0·15 dyne; therefore, the earth's magnetic force was about 0·3 dyne. The dyne is the unit of force of the centimeter gramme-second system of units, and it is equal to about 0·016 of the weight of a grain in the latitude of London; 0·3 dyne is, therefore, equal to about one two-hundredth of a grain, and 0·15 dyne the value of H, to about one four-hundredth of a grain. This small force of the origin of which we are ignorant, keeps the needle true to the pole.—Knowledge.

THE USE OF CONVEX GLASSES FOR DISTANT VISION IN MYOPIA.

By DRS. L. DE WECKER and J. MASSELON.

WE propose to discuss the advantage to be gained in certain cases of myopia from the use of convex glasses for distant vision. Although this seems at first paradoxical, it is unquestionably true that myopes succeed in considerably increasing their sharpness of vision and are enabled to read characters at a distance which they could not distinguish with concave glasses, such, for example, as the name of a street or the number of a house, by placing at some distance in front of the better eye a convex glass, as they would use a lorgnette. The inconvenience of this procedure is in the fact that an inverted image is obtained; but with a little practice inverted characters are easily read, and the facts prove conclusively that this inconvenience is amply compensated for by the increased size of the image, since we know of myopic persons who make habitual use of such glasses.

The method of employing convex glasses in myopia consists in placing the glass before the eye at such a distance that its focus coincides with the punctum remotum. If the myope completely relaxes his accommodation, as he must do under other circumstances, he finds that with the aid of this convex glass the eye is adjusted for parallel rays and can see at a distance. An inverted image is thus obtained, just as the ophthalmoscopic observer receives an inverted image of a myopic eye when, withdrawing from the eye under examination, he adjusts for the punctum remotum of the observed eye, either by the aid of his own accommodation or by the use of a convex lens.

The amount of enlargement of the images of objects observed depends on the amount of myopia and the focus of the convex glass employed. With a given convex lens, the image is enlarged in proportion as the degree of myopia is higher. On the other hand, in equal degrees of myopia the amplification of the image increases with the use of weaker convex lenses. The use of weak convex lenses, in high degrees of myopia, to obtain considerable enlargement, is thus rendered impracticable by the fact that it is necessary to hold the glass at quite a distance from the eye, and the image is so enlarged that the field of vision becomes contracted and a slight movement of the hand which holds the glass results in the disappearance of the object observed.

Practically, glasses weaker than 5 dioptries cannot be employed, and it is desirable that they should be 5 or 6 centimeters in diameter. Under these conditions, the myope, with a little practice, can easily see the objects which he desires to observe, and the visual acuity will be found to be more than double that which is obtained by correcting the myopia with a convex glass, as we have recently had occasion to observe in a case of a person with myopia of 20 dioptries who had accustomed himself to the use of a convex lens.

It will be noticed that with convex lenses a phenomenon occurs exactly opposite to that which is observed in a myopic eye supplied with a concave lens, as in the latter case objects appear diminished in size (a fact which persons having both a myopic eye and an emmetropic or a hypermetropic eye can easily prove); on the other hand, if the myopia is corrected with a convex lens, there is an enlargement of the image, and if the convex lens employed is suitable, the advantages are far superior to those obtained with spectacles.

In conclusion, we think it would be advantageous to extend the use of convex glasses to many cases where, with a high degree of myopia, the visual acuity is defective. Glasses of about +6 dioptries should be prescribed and used like the magnifying glass which certain people use for reading; they thus constitute a magnifying glass for distant vision. Since these glasses produce an inverted image, they are to be used only occasionally, when the myope wishes to see with precision small objects, such, for example, as a public notice, the name of a street, or the number of a house. In these special instances convex lenses will be regarded by certain myopic persons as quite superior to concave lenses, and they will be thankfully accepted as a valuable expedient.

Having had the opportunity of discussing this optical question with Dr. G. Poulain, our colleague desires to add the following note to our communication:

"I have made similar experiments," says Dr. Poulain, "and have been able to increase the visual acuity in several cases of myopia of a high degree; I have also made some attempts at obtaining an erect image.

"I at first attached a convex lens to one of the faces of the right angle of a rectangular prism, and by looking through the other face of the prism, held at a fixed distance from the eye, I was able, on making myself myopic, to see objects erect, but with this inconvenience, that the right side of the object was seen at the left, and vice versa, for the total reflection on the surface of the hypothenuse only caused the image inverted by the lens to be erect in the plane perpendicular to the faces of the prism.

"I then made the experiment of fastening two prisms together by one of the right angle faces in such a way that the edge of one prism was perpendicular to the edge of the other. In this way the image of the object underwent the double erection required. Instead of attaching a convex lens to the incident surface only, I attached one also to the surface of emergence, the refraction of the two lenses being equal to that of the single lens of the first experiment; in this way either face could be used as the incident surface. But with this apparatus, only objects situated at the right or left could be seen, and considerable experience was necessary in order to make use of it. I preferred an arrangement similar to that of Porro's telescope.

"Half of the hypothenuse face of a right angled prism was attached to half of the same face of another right angled prism. On each of the free portions of the hypothenuse faces was attached a lens of 2½ dioptries, and by placing this biprism at a proper distance—that is, such that its focus was at the far point of the myopic eye—objects appeared erect and enlarged.

"Other things being equal, the field increases as the square of the face of emergence, and the weight of the biprism varies as the cube of the same side. This consideration raises an obstacle to the use of such a biprism; if it is too small, the field will be too limited, and if it is large, it will be too heavy.

"I have lately found the experiment on which this communication is based in the Optics of Kepler, Proposition LXXVIII. This scientist, who had a myopia of high degree, without doubt found in his own case this peculiarity of a myopic eye, and I am inclined to think that it was the origin of the invention of his astronomical telescope. He understood that, to place a normal eye in the condition of his own, it sufficed to add to that eye the refractive power which he had in excess.

"In conclusion, I desire to call attention to the phenomena which occur in a hypermetropic eye under similar conditions—that is, in looking through a lens a number of dioptries less than the measure of his own ametropia and placed at a proper distance from the eye. Under such circumstances, the hypermetrope sees objects enlarged and erect, thus simulating Galileo's telescope, as in Kepler's experiment the excess of refraction of the myopic eye replaced the convex ocular of the astronomical telescope."—Annales d'Oculistique, Eng. Ed.

SPONTANEOUS HEATING.

By Dr. RICH. KISSLING.

THE author had the opportunity of studying a case of spontaneous combustion which was checked at its outset. A cask of boiled linseed oil in a warehouse had been leaking on the previous day, and the leakage had been absorbed in sawdust. This sawdust was put in an iron pail, and left in the warehouse all night. About midnight the watchman observed an empyreumatic odor, and saw a slight smoke rising from the pail, which became a flame, when the pail with its contents was carried into the open air. The fire was quenched before the contents had been too much altered by the heat. There can be no doubt that the ignition was spontaneous. The warehouse was lighted electrically, and no matches were ever introduced.

On a careful experimental examination it was found that on passing a current of dry air through raw linseed oil (previously heated to 100°), it gained daily 0·87 per cent. of its weight of the absorption of oxygen. The total increase of weight was 0·41 per cent., and there had been a loss of 0·46 per cent. from the escape of volatile matter—acids of the methane series.

If the surface of contact is between the fatty oils and the air, and if external refrigeration is prevented, a considerable rise of heat is produced by the process of oxidation, which under favorable circumstances may extend to an actual ignition of the fibrous matter.

The quantity of heat liberated by the spontaneous oxidation of the oil depends: (a) on the chemical nature of the oil concerned, i. e., on its affinity for oxygen; (b) on the size of the surface of contact between the oil and the air, i. e., on the mechanical texture of the fibrous or other porous matter, as well as on the relative proportion of the oil and such fibrous matter; (c) on protection against external refrigeration; and (d) on the action of light.

On these conditions it may be remarked, under (a), that the behavior of different oils varies greatly; with rape oil the rise of temperature was not recognizable; with cotton oil it was very trifling; with raw linseed oil stronger; and with boiled oil very considerable. The fibrous substances examined (b) differed likewise. The greatest liberation of heat took place with silk fibers; then followed wool, cotton, jute, and lastly hemp. (c) The protection against refrigeration is of importance, as the tendency of oils to become oxidized with a liberation of heat rises with the temperature. (d) The action of light is similar to that of heat.

The activity of micro-organisms in these processes of oxidation is unimportant.—Zeitschrift Angewandte Chem., January 15, 1895.

(Dr. Kissling omits to state whether the silk fiber used in his experiments was pure or "loaded." The latter article has occasioned serious fires.)—Chem. News.

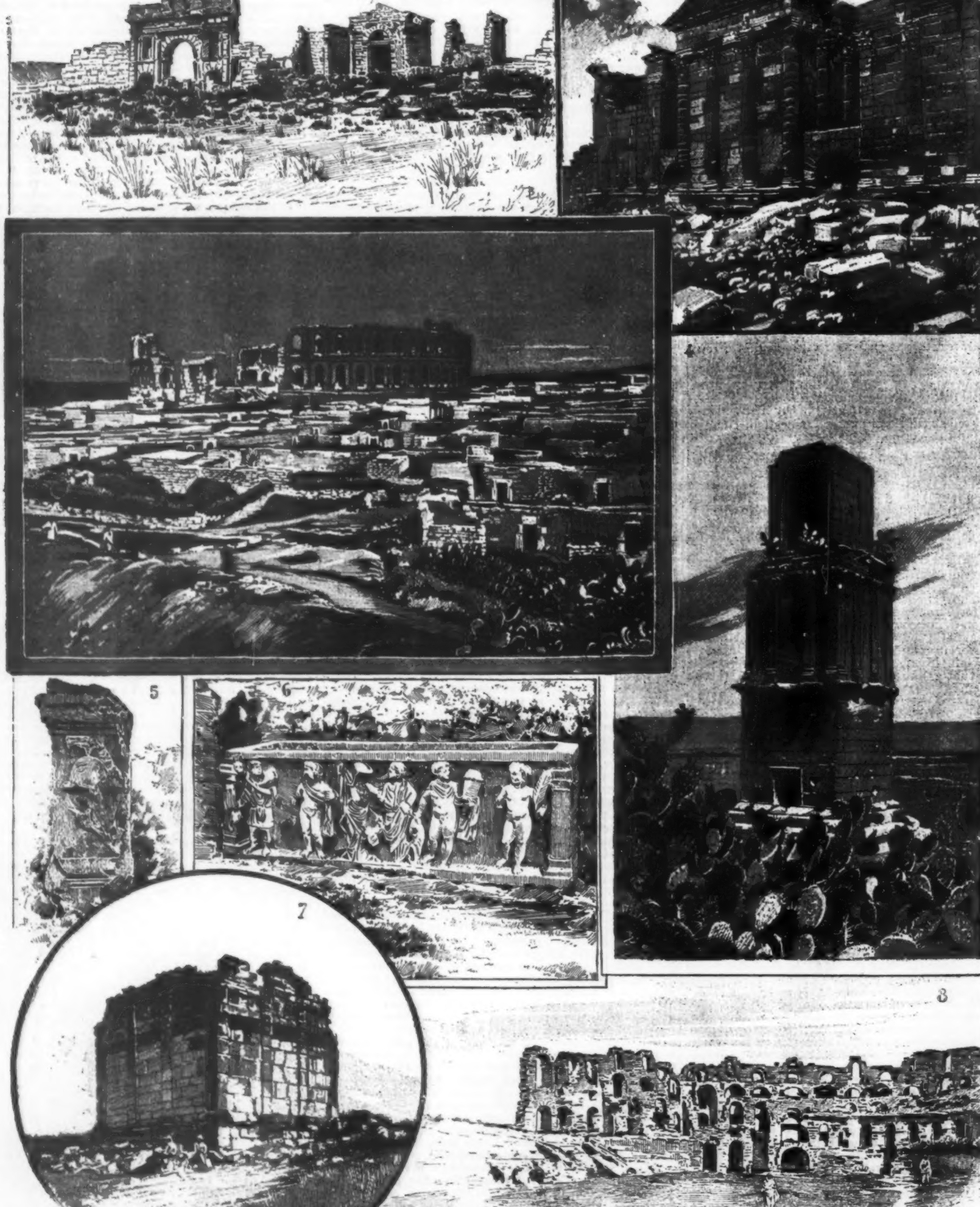
THAT which is popularly known as the funny-bone, at the point of the elbow, is not a bone at all, but a nerve which lies near the surface, and which getting a knock or a blow, causes the well-known tingling sensation in the arms and fingers.

THE ROMAN RUINS OF TUNIS.

ONE of the things that most forcibly impresses the traveler when he visits the regions of the center of Tunis, now deserts, is the innumerable ruins that testify to the wonderful prosperity that they once enjoyed.

Our engravings, made from some of the numerous photographs brought back from his explorations by Dr. Carton, the well-known archæologist, give a good idea of the number and beauty of these vestiges.

When, upon the ruins of El Djem, the ancient Thysdrus, the traveler contemplates the immense arenas, almost equal in extent and majesty to the Coliseum; when, at Sbeitla, he admires its triple temple preceded by an elegant triumphal arch, or he passes under the triumphal gates of which that of Haidra is one of the most beautiful that Africa possesses; when he casts a glance at all those funereal structures by means of which the ancients have transmitted their memory to posterity, mausoleums of large size or simple cippi like that tomb of a veteran studied by Dr. Carton, or like the sarcophagus of white marble ornamented with bass reliefs that Lieutenant Denis



1. The three temples and the gate of triumph, Sbeitla. 2. Rear wall of the three temples. 3. Roman amphitheater, El Djem. 4. Mausoleum of Flavius, at Kasserine. 5. Tomb of a veteran, at Dougga. 6. Roman sarcophagus, Henchir. 7. The Temple of Zamphour. 8. Interior of the amphitheater, El Djem.

THE ROMAN REMAINS IN TUNIS

discovered in the vicinity of Teboursouk; when he stops at Mactar, where Mr. Bordier is exploring with continual good fortune the ruins of the Oppidum Mactaritanum, the traveler asks himself how so prosperous a population as the one that erected all these structures could have disappeared. The answer to this question is found in these same ruins, where formidable Byzantine fortresses, like that of Haidra, bear witness to heroic contests sustained against Islamism. The most remarkable of all these cities combined is most assuredly Dougga, whose Temple of the Capitol is the most perfect piece of architecture of those that Africa possesses. The disengagement of this beautiful edifice, concealed by habitations, was begun by Dr. Carton, who, it will be remembered, exhumed in this same locality, from the twenty-five feet of rubbish that covered it, a theater that ranks among the most beautiful of those that antiquity has bequeathed to us.

It is certain that the points at which the vestiges of these structures and these cities are met with are those that were formerly the most fertile, and at which our colonists still have the best chance of establishing themselves with success.—L'Illustration.

1. A mausoleum in Mactar. 2. The aqueduct of Mactar. 3. A mausoleum. 4. Temple of Jupiter, Dougga. 5. Arch of triumph, Haidra. 6. The Byzantine fortress, Haidra. 7. Roman mausoleum, Haidra.

THE ROMAN REMAINS IN TUNIS.

[From KNOWLEDGE.]

THE CIRCULATION OF WATER IN THE ATMOSPHERE OF MARS.

By CAMILLE FLAMMARION, F.R.A.S.,

Author of "Astronomie Populaire," "Les Etoiles," "Les Terres du Ciel," "La Planète Mars," etc.

THE circulation of water on the earth's surface is necessary for terrestrial life. All living creatures are essentially composed of water—the human body itself contains it in the proportion of seventy per cent.—all require it to live. We have no right, however, to assert that the same law prevails on all the other worlds of the universe; indeed, the study of nature teaches us to be guarded in our assertions, inasmuch as nature herself shows us that she is infinite in the variety of her productions. Should one world be absolutely destitute of water, this is no sufficient reason for us to declare it to be uninhabited. Do not let us attempt to shut up our ideas in a nutshell. Man, deprived of oxygen, dies, yet, even on our little planet, there are beings to which oxygen is fatal.

Still, the orbs of any given planetary system have certain affinities of origin, especially when next door neighbors, like Mars and the earth. On Mars we observe polar snows which are very extensive at the end of every winter, but which by the end of summer have almost entirely disappeared. Is this snow formed of water of the same chemical composition as that of our earth? Possibly, nay, probably, it is.

And what is water? It is an oxide of hydrogen. Now oxygen and hydrogen are diffused through all space, and may be regarded as, in some sort, primordial elements. We may suppose that the combination of those two elements is produced on Mars and Venus in the same manner as on our earth, for all our observations concur in favor of this conclusion.

But the physical condition of water differs in different worlds, varying according to the temperature, atmospheric pressure and dimensions of the planet, the distribution of its climates, its geological and geographical conditions, its destiny, etc. Observation leads us to the conclusion that the circulation of water on the surface of Mars is by no means carried out according to the laws that govern its circulation on the surface of our earth.

Here the mechanism is tolerably simple. Three-quarters of the globe are covered with water, evaporation is considerable, the atmosphere is dense, solar heat perpetually draws off a great quantity of water from the ocean surface, raises it in the form of invisible vapor to a certain height, where it condenses into clouds, and where winds of considerable power, that owe their force directly to the density of our atmosphere, carry the clouds across continents. Thus transported, aqueous vapors, by dissolving into rain or clouds, give their origin to springs, brooks, streams and rivers, and bear back to the sea the water that has been raised from it by the action of the sun's rays.

We may estimate the volume of water thus annually carried off by the atmosphere at 721 trillions (721×10^{12}) of cubic meters—that is to say, about the 4,400th part of the total amount of sea water, which is estimated at 3,200 quadrillions of cubic meters. Supposing the ocean bed were emptied, it would take forty-four thousand years for all the tidal rivers of the world to fill it again. The solar heat used in effecting this process of evaporation of watery vapor thus raised to the mean height of the clouds would melt eleven thousand millions of cubic meters of iron a year—that is to say, a much more considerable mass than the whole mountain range of the Alps.

In the space of a year each square meter of the earth's surface receives 2,318,157 of calories—i. e., more than twenty-three thousand millions of calories per French hectare, that is to say 9,852,200,000,000 kilogrammeters. The sun's heat radiation exercised on one of our hectares develops over that area, under a thousand varied forms, a power equivalent to the continuous working of 4,163 horse power. Over the whole earth its force is of 510 sextillions of kilogrammeters, or 217,316,000,000,000 horse power.

But very different conditions obtain on the surface of Mars. In the first place, the heat which that planet receives from the sun is less, its distance being 1·52, or about half as much again as that of the earth, and the quantity of heat being 0·43, say less by more than one-half than we receive here. But, on the other hand, on Mars the year is nearly as long again as our year, being of 688 or 689 days.

The heat accumulated on one of its hemispheres during summer would suffice to melt a thick layer of snow, although on the earth, which is nearer the sun, the six months of the summer season are not sufficient to do so. When the snow begins to melt, a small supply of additional heat is often sufficient to complete the dissolving process.

We must now consider another point of the greatest importance. Our terrestrial atmosphere is very heavy. At the sea level this atmospheric pressure is equivalent to a column of mercury of 0·760 meter.

The pressure is of 1,033 grammes to the square centimeter, or of 103 kilogrammes to the square decimeter, or 10,330 kilogrammes to the square meter. Now, the earth's total superficies is of about 510 millions of square kilometers; the whole atmosphere, therefore, weighs 5 quintillions 268 quadrillions of kilogrammes—that is to say, a little less than the millionth part of the weight of our terrestrial globe.

The Martian atmosphere is incomparably lighter. Gravity at the surface of Mars being much feebler than at the surface of our earth (0·376), all bodies there weigh less in the same proportion, and the atmosphere is in the same case. If every square meter of the surface of Mars supported the same atmosphere as ours, the pressure of that atmosphere would be reduced in the preceding proportion; that is to say, that the barometer, instead of being at 760 millimeters at the sea level, would only be at 286 millimeters. This is the pressure which we find in a balloon at a height of 8,000 meters, or on the summits of lofty mountains. At the summit of Mont Blanc the pressure is one of 424 millimeters.

It is very certain that the atmosphere of Mars is not analogous to ours, and that water there is not in the same condition as with us; for if it were so, the temperature at the planet's surface would be below zero, even without taking into account its greater distance from the sun, and we should have before our eyes a globe of ice, which is not the case. On the contrary, we discover on Mars snow confined within well defined limits, and these limits vary with the temperature, and if we observe a Martian hemisphere during its summer, it has less snow at its pole than we have at ours. Those patches of snow that we perceive from time to time at certain points of the temperate regions are also melted.

Both observation and calculation bring us to the conclusion that this atmosphere of Mars is less dense than ours, that it forms less cloud, that its currents have less intensity, that its winds are never very high, and that it is visited by no tempests. Its conditions as to density and pressure are very different from those that prevail here. On Mars, evaporation must be easy and rapid; the boiling point there is doubtless about 46°, instead of 100°. The zero point at which water freezes is not the same as on our planet. Its atmosphere cannot be either chemically or physically the same as ours.

Its mean temperature may be higher than that of the earth. The effects observed correspond to a higher mean degree of ambient heat relatively to the collective conditions of both planets.

We know that the atmosphere serves as a hothouse for the conservation of the heat derived from the sun, and to prevent its loss by radiation into space, but it is not air properly speaking—the mixture of oxygen and nitrogen—that possesses this property, but aqueous vapor. A molecule of water vapor is 16,000 times more efficacious than a molecule of dry air in preserving heat. Nor is water the only body that can boast of this property. The vapors of sulphuric, formic and acetic ethers, of amylene, ethyl iodide, chloroform and carbon bisulphide possess it likewise. The atmosphere of Mars, rarefied as it certainly is, can hold vapors of this kind in suspension, and preserve at the planet's surface a temperature equal to or even higher than the mean temperature of the earth.

But it is scarcely necessary to imagine anything else than water analogous to ours, since the Martian snow so closely resembles our snow in its winter invasions and summer dissolution, and by the inundations by which its melting is followed, that we may look upon it as almost identical with ours.

The real difference is in the mode of circulation. On Mars, oceanic evaporation does not give rise, as with us, to clouds, rains, springs and rivers.

None of the great watercourses with which we are acquainted on Mars finds its source on terra firma. We see nothing but canals running from one sea to another. Every canal begins and ends either in a sea or in a lake, or in another canal, or, lastly, at the intersection of several other canals, but none of them has ever been brought to an abrupt conclusion in the midst of land—a fact which is of the highest importance. Moreover, they intersect each other at every possible angle.

Clouds, on the other hand, are extremely rare on Mars, and perhaps they are only thin mists or light cirrus. They are certainly not clouds of rain or tempest. At the time of the last opposition of 1894, at the observatory of Juvisy, when we had our eyes, so to speak, constantly fixed on Mars, the planet showed itself to us, as usual, perpetually clear, with the exception of the 10th of October and for a few days after, during which I ascertained that the Cimmerian and Tyrrhenian Seas were masked by a veil of clouds. These veils are very rare on Mars, whereas on the earth they are perpetual. There is, perhaps, not a single day in the year on which the whole surface of the earth can be discovered and clearly seen in space. In short, the meteorological conditions prevailing in the two worlds are absolutely unlike.

Furthermore, in the highly rarefied atmosphere of Mars, there are no intense winds, nothing analogous to our trade winds, or to the regime of predominant winds which govern our terrestrial climates. Sometimes we can perceive very long trails of snow, apparently produced by currents in a tranquil atmosphere, as, for instance, those which Mr. Schiaparelli observed in November and December, 1881, round the north pole and extending very far (vide "The Planet Mars," p. 741, Fig. 263); but these are exceptions. Fine weather is the normal state of the Martian climates.

Of course, we must not deceive ourselves as to the accuracy of our Martian knowledge. We do not see everything. We have never seen the delicate ramifications which may characterize the canals. We know neither the width of the narrowest nor the laws which govern their periodical duplication; and it was only the other day that we ascertained indubitably that they transport the sea waters from one point to another. Mr. Maunder was perfectly right in thinking that "we cannot assume that what we are able to discern is really the ultimate structure of the body we are examining." This ignorance of ours may hide a whole world of unknown realities. Nevertheless, we may, perhaps, try to form some idea of what takes place in the circulation of its waters.

The melting of the polar snow almost always gives rise to inundations over immense tracts of land, over hundreds of thousands of square kilometers. The seas encroach far into the interior of the lands; the canals grow wider; fresh canals, often of great magnitude, appear; and islands, peninsulas, and portions of continents become submerged. Everything proves to us that the surface of the planet is one immense plain, and that mountains are very rare.

The canals may be natural grooves due to the evolution of the planet itself, just as the English and the Mozambique Channels are on our earth, or they may be furrows dug by the inhabitants for the distribution of their waters, or they may be both—that is to say, they may be natural formations, rectified by intelligence. We will not attempt, as some have done, to calculate the work represented by the construction of this geometrical network, for the conditions of the planet's surface, the nature of its materials, its density and gravity, the muscular force, machinery, and character of its humanity, are so different from terrestrial conditions that there can be no analogy between them. But what is certain is that these canals serve to effect the circulation of water, and constitute a hydrographic system of the most ingenious character. It may be objected that this admirable system does not prevent inundations. No; but it regulates them; it is, as it were, a Nile embanked and controlled in its course.

The periodical inundation caused each Martian summer by the melting of the snows is distributed far and wide by this network of canals, which seem to be the chief, if not the only means by which water, and with it organic life, can be distributed over the surface of this planet. At this season the canals appear encompassed by a dark zone forming a species of temporary sea. The canals of the surrounding region then become darker and wider, and cover vast tracts of land. Things remain in this state until the polar snow is at its minimum. The melting process is at an end, the breadth of the canals diminishes, the temporary seas disappear, and the continents become yellow once more. This great phenomenon occurs in all the region comprised between the pole and the sixtieth degree of latitude, and is renewed every summer. Over the planet's whole surface the canal system is unstable. When the canals become troubled, and their contours doubtful and ill defined, it seems as if the water must be very low, or have entirely disappeared. Nothing remains where the canals once were; or, rather, we descry a yellowish streak, differing very little from the surrounding territory. In the months that precede and follow the great northern inundation, toward the period of the equinoxes, the canals become doubled. In consequence of a rapid modification which is effected in a few days, perhaps even in a few hours, such and such a canal is transformed throughout its whole length into two parallel lines, which run with the geometrical precision of the two rails of a railway, and follow the exact direction of the primitive canal. These newer canals have, like the first, a width of from fifty to a hundred kilometers or more, and are separated by an interval of from fifty to five or six hundred kilometers. The color of these lines varies from black to red, and is easily distinguishable from the yellow of the continents. The intermediary space is generally yellow, sometimes whitish. This gemination also takes place in the lakes, which become duplicated as well.

Whatever may be the explanation of these changes, unknown to our earth, we may conclude that on the surface of the planet Mars water circulates, not by a system of clouds, rains or springs like ours, but by the melting of the polar snow, and by the horizontal and interlaced canals which distribute it over the entire body of the continents. Then it seems to evaporate and to become condensed almost solely on the colder polar zones, which receive it in the state of snow.

Mars, then, is quite another world, differing greatly from the one we inhabit, yet no less alive than ours, in more active motion, and more agitated in some respects, though with a climate which is doubtless very agreeable from the constant serenity and from the absence of inclement weather, rains and tempests, which characterize, unhappily, the great majority of earthly climates. The days are slightly longer there than with us, and the year is nearly twice as long as ours.

TEA CULTIVATION IN THE CAUCASUS.

EXPERIMENTS with tea plants in the Russian province of Transcaucasia have been carried on for some time. In the Russian Nouvelles, quoted by the Board of Trade Journal (1891, p. 174), it was stated that "the tea plant flourished on the western littoral of Transcaucasia, notably at Soukhourn. The tea shrubs planted in those districts reach normal dimensions and arrive at full maturity, producing excellent seeds. The climate of Western Caucasia compares favorably with that of the southeast of China. The analogy consists not only in the equality of the mean annual temperature of the two regions, but also in the quantity of rain which falls there and in the period (spring) when the rains are most abundant, a condition essential to the growth of the tea plant." It is added that a so-called Caucasian tea had been exhibited at the Nijni-Novgorod fair. "This was nothing else but Vaccinium Arctostaphylos, a kind of tea from Koporie, which only served to discredit the future plantations in Caucasia."

Latterly the tea plantations in the Caucasus have been extended, and "the quality of the tea produced is said to be good."

The Department of Crown Estates has appointed a commission, which will include the inspector of the imperial domains in the Caucasus, to proceed to India, Southern China, and Ceylon, with the object of thoroughly examining the methods of tea culture and curing in those countries. The commercial agent for the Appanage Department of the Russian Imperial Court has recently visited Kew to study the subject.

Some remarkable statistics as to the tea production of the world are given in a paper read by Mr. A. G. Stanton at the Society of Arts (Jour., vol. 43, pp. 189-201). In 1883 the total consumption of tea in the United Kingdom was 170,780,000 lb., or 4·82 lb. per head of population. In 1894 these figures had risen to 214,341,044 lb., or 5·53 lb. per head.

The remarkable feature in the statistics is the way in which India and Ceylon have displaced China as a source of supply. Taking Mr. Stanton's percentages, the proportions of the total supply stand as follows:

	China.	India.	Ceylon.
1883	66	33	1
1894	12	55	33

In twelve years Ceylon has pushed to the position at first occupied by India, and this almost entirely at the expense of China.

Mr. Stanton states: "The annual consumption of tea in the civilized world, exclusive of the United Kingdom, is about 250,000,000 lb. Of this quantity only about 30,000,000 lb. are Indian and Ceylon." It is evident, then, that if Russian tea can be successfully placed upon the market, it will have, in the first instance at any rate, to compete with China tea. The new competitor is not likely seriously to affect British production.

As the experiment to grow tea in the Russian em-

pire possesses an interest in connection with the large tea industries of India and Ceylon, the following particulars are reproduced from the report for the year 1894 on the agricultural condition of the Batoum consular district, lately fowarded to the Earl of Kimberley by Mr. Consul Stevens. [Foreign Office, Annual Series, 1894, No. 1,481.]

The tea plantations at Chakva, near Batoum, belonging to Messrs. K. & S. Popoff, tea merchants, of Moscow, have been considerably extended this year under the supervision of the Chinese tea planters, who were brought over in 1893; a large number, about 600, natives of the Caucasus, are also employed in working on the plantation of this firm.

In a letter to the Caucasian Agricultural News, Mr. A. Solovtzoff, who for several years past has been cultivating tea on his estates at no great distance from the lands belonging to Messrs. Popoff, gives a somewhat interesting account of his experiences in the raising of this plant since the year 1884. He states that at that time his chief concern was the question of procuring tea plants for planting. He feared to order seed lest old seed should be sent; besides this, the seed of tea contains a volatile oil in considerable quantity which, during a long voyage, would be likely to evaporate, and thus the seed would have been rendered sterile. Even the seed raised at Chakva requires the greatest care and attention, as excessive dryness deprives it of the oil and too much damp causes it to rot.

Eventually, however, he succeeded in obtaining a few plants which arrived at Batoum in the month of July, 1885, together with some seedlings. The condition of both left much to be desired, as they had received but little care and water during their transit, and were to a great extent damaged by the customs authorities, who used quicklime for the purpose of disinfecting them against the importation of Phylloxera. They were, subsequently, transplanted to Chakva, and with as little delay as possible planted on his property. At first they grew badly, and all the shrubs dried up, but some of the seedlings took, and from these he was able to develop his plantation.

The land chosen for the plantation was a red clayey soil, dressed with a thin coat of manure composed of thoroughly rotted leaves and branches, etc., that had fallen from the trees. After clearing away the manure the land was dug up for a depth of about 21 inches, and the top soil was worked to the bottom.

The seeds ripen in the course of a year, and are gathered in the month of October, at which time the plant also flowers. The seeds, after being collected, are strewed with dry sand and are kept in earthenware vessels. In March they are damped with a solution of camphor, spirits and water, in order to force their growth. The seeds are left damped with this solution for some hours, and are then put back into the earthenware vessels, after being mixed with damp earth. In this earth the seeds begin to shoot up, and they are then transplanted into the nursery beds, the soil of which is the same as that of the plantation, but which has a certain proportion of sea sand admixed for the purpose of rendering it more friable. The seeds are sown at a distance of 3½ inches apart at a depth of 1¾ inches. As soon as the young shoots make their appearance above ground it is necessary to cover them with mats in order to protect them from the excessive heat of the sun; but this protection should be removed in rainy weather and at night. In dry weather the young seedlings have to be watered once a day, and under this system of cultivation it is found that every seed comes up. Mole crickets, however, create great havoc among the seeds. These insects, Mr. Solovtzoff says, are the only enemies of the seedlings with which he has to contend, and they are most difficult to deal with, although it would appear he has found means whereby the ravages caused by mole crickets may be minimized. The methods which he adopts to attain this end are the annual removal of the nursery beds to fresh ground, and the burying in the nursery beds, in a line with the burrows of the crickets, of grains of Indian corn boiled in a solution of arsenic, or, what is still better, a solution of corrosive sublimate.

The propagation of the tea plant by means of cuttings should be avoided, as a large proportion of the cuttings do not take, but the chief objection is that those that do only produce very weak plants.

Now that he has an almost unlimited supply of seedlings, Mr. Solovtzoff intends transplanting only the stronger ones into the plantation. The seedlings remain in the beds a whole year, and are then planted out 4 feet apart from each other.

The only attention which the plantation requires is that it should be freed from weeds twice a year. For the first year the young plants should be protected from the rays of the sun by the branches of trees. It has not yet been found necessary to artificially water the plants in the plantation. Up to the present pruning, with a view to increasing the crop of leaves, has not been resorted to, as the chief object has been to obtain as large a quantity of seed as possible for the multiplication of the plants. No manure has been used hitherto, but when planting out the seedlings this year it was intended to manure the soil with timber ashes and refuse from oil mills.

During the dry season, May and June, when the heat is very great, the grown-up plants stand the climate very well, but, as mentioned before, the young plants have to be protected from the sun. The winter of 1892-93 was exceptionally rigorous, the frosts being as severe as 6° Reaumur, but neither the grown-up plants nor the seedlings suffered in any way, although the latter were for several days covered with snow up to the very leaves. This result is particularly gratifying when the fact that the very young seedlings are planted in a quite open and low-lying plain fully exposed to the wind is taken into consideration; when subsequently transferred to the plantation they do very well.

The plantation covers about five acres, and as planting has been carried on as seed has become available, it contains plants of all sizes, ranging from five years' growth to one and a half years' growth. The number of plants was 5,150, and about 8,000 seedlings were to be planted out during the present year. There is a sufficient quantity of seed in stock to raise 40,000 more seedlings, and the quality of the tea is said to be good.

It is also reported that about 43,000 acres of government land in the neighborhood of Chakva have recently been purchased by the Department of Crown Estates for the purpose of turning them into tea plantations, and in connection with this, the above department has ordered a commission, which will include the inspector of imperial domains in the Caucasus, to proceed, at the end of this year, to India, Southern China, and Ceylon, with the object of thoroughly studying the methods of tea culture in those countries. —Kew Bulletin.

EXPERIMENTAL EVOLUTION AMONG PLANTS.*

By L. H. Bailey.

De Varigny has written a most suggestive book upon Experimental Evolution, in which he contends for the establishment of an institution where experiments can be definitely undertaken for the purpose of transforming a species into a new species. "In experimental transformism," he writes, "lies the only test which we can apply to the evolutionary theory. We must use all the methods we are acquainted with, and also those, yet unknown, which cannot fail to disclose themselves when we begin a thorough investigation of the matter, and do our utmost to bring about the transmutation of any species. We do not specially desire to transform any one species into another known at present; we wish to transform it into a new species. . . . Experimental transformism is what we need now, and therein lies the only method we can use."

This is a most commendable object, and I hope that the attempt will be made to create a new species before our very eyes. This is what most people demand as a proof of evolution, and they are sometimes impatient that it has not been done; and it would seem, upon the face of it, that nothing more could be desired. When I reflect, however, upon the fact that this very thing has occurred time and again with the horticulturist, and consider that botanists and philosophers persist in refusing to see it, I am constrained to offer some suggestions upon De Varigny's excellent ambition. If I show a botanist a horticultural type of recent or even contemporaneous origin which I consider to be specifically distinct from its ancestors, he at once exclaims that it is not a species but a horticultural variety. If I ask him why, he replies, "Because it is an artificial production!" If I show him that the type is just as distinct from the species from which it sprung as that species is from its related species, and that it reproduces its kind with just as much certainty, he still replies that because it is a horticultural production it cannot be a species. In what, then, does an accidental horticultural origin differ from any other origin? Simply in the fact that one takes place under the eye of man and the other occurs somewhere else! It is impossible at the present day to make a definition of a species which shall exclude many horticultural types, unless an arbitrary exception is made of them. The old definitions assumed that species are special creative acts, and the method of origin is therefore stated or implied in all of them. The definition itself, therefore, was essentially a statement of the impossibility of evolution. We have now revised our definitions so as to exclude the matter of origin, and thereby allow free course to evolution studies; and yet here is a great class of natural objects which is practically eliminated from our consideration because, unhappily, we know whence the forms came! Or, to state the case differently, these types cannot be accepted as proofs of the transformation of species because we know certainly that they are the result of transformation!

Now, just this state of things would be sure to occur if De Varigny were to transform one species into another. People would say that the new form is not really a species, because it is the result of cultivation, domestication and definite breeding by man. He could never hope to secure more remarkable transformations than have occurred a thousand times in the garden; and his scheme—so far as it applies to plants—is essentially that followed by all good gardeners. Or, if the prejudices of critics respecting the so-called artificial production of species could be overcome, he could just as well draw his proofs of evolution from what has already been done with cultivated plants and domesticated animals, as from similar results which might arise in the future from his independent efforts. I am not arguing against the scheme to create a species before our eyes, but I am simply stating what has been and is the insurmountable difficulty in just this line of endeavor—the inability of the experimenter to satisfy some scientific men that he has really produced a species; for it is a singular thing that while all biologists now agree in defining a species upon its tangible and present characters, many of them nevertheless act upon the old notion that a species must have its origin somewhere beyond the domain of exact history.

This notion that a species, to be a species, must have originated in nature's garden and not in man's, has been left over to us from the last generation—it is the inheritance of an acquired character. John Ray, toward the close of the seventeenth century, appears to have been the first to use the word species in its technical natural history sense, and the matter of origin was an important factor in his conception of what a species is. Linnæus' phrase is familiar: "We reckon as many species as there were forms created in the beginning."

Darwin elaborated the new conception—that a species is simply a congregation of individuals which are more like each other than they are like any other congregation—and with a freedom from prejudice which is rarely attained even by his most devoted adherents, he declared that "one new variety raised by man will be a more important and interesting subject for study than one more species added to the infinitude of already recorded species." The old naturalists threw the origin of the species back beyond known causes. Darwin endeavored to discover the "Origin of Species," and it is significant that he set out without giving any definition of what a species is. I have said this much for the purpose of showing that it is important, when we demand that a new species be created as a proof of evolution, that we are ourselves open to the conviction that the thing can be done.

I have said that no modern naturalist would define a species in such terms that some horticultural types could be excluded, even if he desired that they should be omitted. Haeckel's excellent definition admits many of them. In his view, the word species "serves as the common designation of all individual animals or plants, which are equal in all essential matters of form, and are only distinguished by quite subordinate characters." It is impossible, however, to actually determine if one has a species in hand by applying a definition. One must show that his new type—if it is a plant—has botanical characters as well marked as similar accepted species have, and these characters must show, as a whole, a general tendency toward permanency when the plant is normally propagated by seeds. He must measure his type by the rule of accepted botanical practice. If the same plant were found wild, so that all prejudice might be removed, would the botanist unhesitatingly describe it as a new species? If yes, then we should say that a new species had been created under the hand of man; and this rule I wish now to apply to a very few familiar plants. In doing so, I do not wish to be understood as saying that I consider it advisable to describe these plants as species under the existing methods of botanical description and nomenclature, for merely as a matter of convenience and perspicuity, I do not; but I wish to show that they really are, in every essential character, just as much species as very many other universally accepted species are.

[The speaker then produced numerous instances of the evolution of forms of garden plants, in various genera, which are as distinct from their parents and from each other as accepted species of the same genus are; and these forms are as permanent, when multiplied extensively through many years by means of the seeds, as these wild species are. "Here we have absolutely new and unique types, as De Varigny demands, and they are as distinct from each other and from their parents, in accepted botanical characters, as 'good species' in the same genus are from each other, and they perpetuate these characters as unequivocally as those species do. Moreover, we know definitely what their origins were, and they therefore answer all the purposes of experimental evolution.

"All this is but another illustration of how tenaciously botanists still hold to the Linnæan idea of species, while they profess the Darwinian idea."]

I have now brought to your attention a few familiar plants for the purpose of showing that what are, to all intents and purposes, good species have originated in recent years, and that, while botanists demand that the origination of species within historic times shall constitute the only indisputable proof of organic evolution, they nevertheless refuse to accept as species those forms which have thus originated and which answer every demand of their definitions and practice. The proofs of the evolution of species, drawn from the accepted practice of the best botanists themselves, could be indefinitely extended. We need only recall the botanical confusion in which most cultivated plants now lie, to find abundant proof of the evolution of hundreds of types so distinct that the best botanists have considered them to be species; but other botanists, basing their estimate of species upon origins, have reduced them or reincluded them into the form or type first described. Consider the numb r of species which have been made in the genus Citrus, comprising the various oranges, lemons, limes and the like.

Recall the roses. The moss rose and others would be regarded as distinct species by any botanist if they were found wild and if they held their characters as tenaciously as they do under cultivation. In fact, the moss rose was long regarded as a good species, and it was only when its origin began to be understood that this opinion was given up. The earlier botanists, who were less critical about origins than the present botanists are, made species largely upon apparent features of plants, although their fundamental conception of a species was one which was created, as we find it, in the beginning. Yet, strangely enough, we at the present day profess to regard species as nothing more than loose and conventional aggregations of similar individuals and which we conceive to have sprung from a common ancestor at some more or less late epoch in the world's history—we make our species upon premises which we deny, by giving greater weight to obscurity of origin than we do to similarities of individuals.

The fact is that much of the practice of systematic or descriptive botany is at variance with the teachings of evolution. Every naturalist now knows that nature does not set out to make species. She makes a multitude of forms which we, merely for purposes of convenience in classifying our knowledge of them, combine into more or less marked aggregations to which we have given the name species. Now and then we find in nature an aggregation of successive individuals which is so well marked and set off from its associated groups, that we think nature to have made an out and out distinct species. But a closer acquaintance with such species shows that, in many cases, the intermediate or outlying forms have been lost and that the type which we now know is the remainder in a continuous problem of subtraction. In other cases, it appears to have arisen without intermediate forms, as a distinct offshoot from an older type. This is well illustrated in many remarkably distinct garden forms, which originated all at once with characters new to the species or even to the genus. I have mentioned such a case in the upright tomato. Even the sudden appearance of these strange forms is proof that species may originate at any time and that it can be no part of our fundamental conception of a species that it shall have originated in some remote epoch. Species-making forever enforces the idea of the distinctness and immutability of organic forms, but study of organisms themselves forever enforces an opposite conception. The intermediate and variable forms are perplexities to one who attempts to describe species as so many entities which have distinct and personal attributes. So the garden has always been the bugbear of the botanist. Even our lamented Asa Gray declared that the modern garden roses are "too much mixed by crossing and changed by variation to be subjects of botanical study." He meant to say that the roses are too much modified to allow of species-making. The despair of systematic botanists is the proof of evolution!

I repeat that mere species-making, in the old or con-

* Abstract of an address before the Massachusetts Horticultural Society, Boston, Feb. 22, 1895.—Amer. Naturalist.

ventional sense, is an incubus to the study of nature. One who now describes a species should feel that he is simply describing a variable and plastic group of individuals for mere convenience' sake. He should not attempt to draw the boundary lines hard and fast, nor should he be annoyed if he is obliged to modify his description every year. This loose group may contain some forms which seem to be aberrant to the idea which he has in mind; and it would seem as if he should be ready to call them new or distinct species whenever, from whatever cause, they become so much modified that it is convenient, for purposes of identification and description, to separate them from the general type. Just as soon as botanists come to feel that all so-called species of plants are transitory and artificial groups maintained for convenience in the study of nature, they will not ask whether they are modified outside the garden or inside it, but will consider groups of equal distinctness and permanence to be of equal value in the classification of knowledge, wholly aside from the mere place of their origin. At the present time, the garden fence is the only distinction between many accepted species and many discarded ones. The cultivation of man differs from the methods of nature only in degree, not in kind; and if man secures results sooner than nature does it is only another and indubitable proof of the evolution of organic forms. It is certainly a wholly unscientific attitude to demand that forms originating by one of nature's methods are species, while similar forms originating by another method are beneath notice.

If species are not original entities in nature, then it is useless to quarrel over the origination of them by experiment. All we want to know, as a proof of evolution, is whether plants and animals can become profoundly modified under different conditions, and if these modifications tend to persist. Every man before me knows, as a matter of common observation and practice, that this is true of plants. He knows that varieties with the most marked features are passing before him like a moving panorama. He knows that nearly every plant which has been long cultivated has become so profoundly and irrevocably modified that people are disputing as to what wild species it came from. Consider that we cannot certainly identify the original species of the apple, peach, plum, cherry, orange, lemon, wine grape, sweet potato, Indian corn, melon, bean, pumpkin, wheat, tobacco, chrysanthemum, and nearly or quite a hundred other common cultivated plants. It is immaterial whether they are called species or varieties. They are new forms. Some of them are so distinct that they have been regarded as belonging to distinct genera. Here is the experiment to prove that evolution is true, worked out upon a scale and with a definiteness of detail which the boldest experimenter could not hope to obtain, were he to live a thousand years. The horticulturist is the only man in the world whose distinct business and profession is evolution. He, of all other men, has the experimental proof that species come and go.

TO CENTRAL SIBERIA BY WATER.

CAPTAIN WIGGINS, looking none the worse for his shipwreck and loss of his steamer the Stjernen in the Kara Sea, adjusted his spectacles on his nose and deftly traced on a piece of paper the route he had followed in his last perilous voyage. He had only arrived in London recently, and was already deep in his preparations for another Siberian journey, when a representative of the Daily Graphic surprised him at the Great Northern Hotel.

"But for this accident to the Stjernen," said the captain, pointing to a mark he had made on his rough chart, "the journey would have been quite uneventful. Indeed, there is nothing very astonishing now in getting to the heart of Siberia by water. The practicability of the Yenissei route is not only definitely established from the scientific point of view, but its importance is acknowledged by the Russian government and the whole commercial community."

"Will not the fate of the Stjernen tend to raise fresh misgivings on the subject?"

"Not at all. The accident might have occurred anywhere. It had nothing whatever to do with the ice or even with the Yenissei, for we were only six hours' journey from the White Sea at the time. We were the victims of bad weather—of fog and rain and wind, such as might have occurred in the Mediterranean—when we struck the coast northwest of the mouth of the Obi.

"It was a tremendous thump," continued the captain, "and there was nothing for it but to take to the boats. In spite of the rolling waves and the storm, which increased in fury every moment, we managed to bring all the men, provisions, and tents safely ashore. There were forty-nine of us altogether. The next day my friend Mr. Hugh Popham started with two sailors and a servant to get assistance. He thought of walking to Chabarova, a large village and trading station built by Alexander Sibiriakoff, the wealthy gold mine owner. After tramping fifteen miles, steering his way by the aid of a pocket compass, he came across a native choom or tent occupied by several Russians. By good luck there happened to be among them a friend of mine, Ivan Alexandrovitch Kosheven, and he at once organized a rescue for us. With his partner, and a Samoyede and his daughter, he brought us, the following day, five sledges laden with skins and meat. Then came twenty more sledges with innumerable reindeer, and in them we were all enabled to set out for Chabarova. Here we spent three weeks getting ready for the further overland journey. On October 20 we started for Archangel in eighty-seven sledges divided into three parties traveling independently of each other, with separate Samoyede guides. Snow fell to a depth of eight inches, and the traveling was fast and easy. I was in the first sledge, with five reindeer abreast. Every night we encamped in chooms, and let the reindeer run loose in search of fodder, but by six in the morning we were again on the road. Traveling in this way for eighteen days we reached Povostoshersk, whence we dispatched a special messenger with a telegram for the British consul at Archangel. Our next stoppage was at Ostjelma, where we exchanged our deer for horses, and a few days afterward we were safe at Archangel."

"Any accidents on the road?"

"None of any importance. Some of the sledges broke down, but they were speedily and most skillfully repaired by their Samoyede drivers. Then we occasionally came on the tracks of wolves, and one night they carried off two of our deer, but we did not make their personal acquaintance. What we suffered most from, however, was the cold. After leaving Povostoshersk the temperature fell below anything our thermometers would register, although the weather was otherwise bright and fine. So cold was it that we could not touch wood with the naked finger without leaving the skin behind. The natives did not seem to be in the least affected by it, but some of my poor fellows were severely frostbitten. We left five of them in hospital at Archangel, and one had to have his foot amputated."

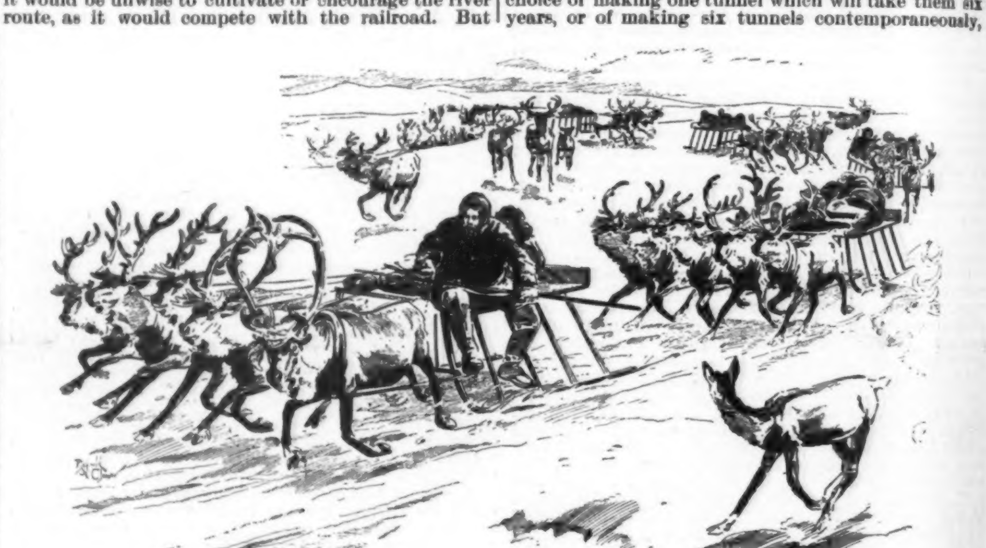
"And now what are the prospects of the Yenissei route?"

"Better than ever," answered the captain with a broad smile of intensest satisfaction. "I have knocked it into the Russians at last that the Yenissei is as essential to the prosperity of Siberia as the great Trunk Railway. It hasn't been easy work, I assure you. Twenty years ago they wouldn't believe me when I told them that the Kara Sea was open for three months every year for navigation. When I proved my words, they did not give much attention to them until they began building the Siberian Railway. Then the problem of transporting rails began to perplex them, especially after they had made some progress with the eastern and western sections. To carry rails half way round the world to Vladivostock, and then overland into the interior, was obviously absurd when there was a splendid waterway from the north navigable right down to the center of the projected railroad. One day they wired to me from St. Petersburg: 'Can you bring 2,000 tons of rails down the Yenissei to Krasnojarsk?' I wired back: 'Twenty thousand, if you like.' I took that lot of rails and landed it safely at Krasnojarsk, where the Yenissei strikes the site of the railroad, 2,700 miles from the coast. Why, sir, the feat took their breath away!"

"After that, I suppose, all was plain sailing?"

"Not entirely. Some people started the idea that it would be unwise to cultivate or encourage the river route, as it would compete with the railroad. But

thick with the equivalent of the Vancouver pine for thousands of miles, to the mineral districts with gold and silver mines, with coal and iron, and beyond these again to the southern cereal districts. The tributaries of the river tapped China with its tea and silks. "And," added the captain with a sudden descent into prose, "the current of the river runs about five knots an hour." The Yenissei runs into the Kara Sea, and it is this water route to Siberia which Captain Wiggins has been traversing for twenty years past, and which he particularly wishes to recommend to the British trader. His last adventure in connection with it was, as we know, not a very fortunate one, since his ship, the Stjernen, ran aground; but as that was the only accident in ten years, and the only vessel out of thirty-seven which he has taken through the iron gates of Kara, the loss does not cast much doubt upon the reliability or safety of the way. The thing which is most to be feared in the Kara Sea is not the ice, but the fog. It was this fog, lasting the unprecedentedly long time of five days, which, together with the currents, took the Stjernen out of her reckonings and laid her up on the coast thirty miles west of the river mouth. As for the ice which shuts the iron gates in June, but which sails northward to the Pole in August, the only necessary precaution is to steam round the floe fields; and with regard to this ice there is this fact to be observed—that the Kara, being a sea open to the Pole, the ice carried by the Gulf Stream out of the sea never returns to trouble the mariner again. The great point, however, which Captain Wiggins desired to make was that the vessels of the present day can do the trade; at the most they want an "Arctic" steamer to convoy them. And the lecturer pointed out that during the last twenty years 200 Norwegian vessels had been employed in the sea, walrus and seal hunting. The latter part of the address was given to a description of the great Trans-Siberian Railway; to the development of the theory of the way in which the railroad and the Yenissei waterway should complement one another. The railroad has a stiff task in front of it. It has not only desert land to cross, but rivers to bridge and mountains to cut through. In the region of Lake Baikal its engineers are confronted with the choice of making one tunnel which will take them six years, or of making six tunnels contemporaneously,



REINDEER TRAVELING IN SIBERIA.

this delusion I also soon knocked on the head. I proved to them not only that there was room for both, but that they would be the natural complements of each other. In the first place, the railway will never suffice for the carrying trade of Siberia. Chinese teas alone will monopolize it. But even if it were equal to the demands which will be made upon it, there are certain classes of merchandise, such as cereals and minerals, which it could not carry on account of the heavy cost of freight. Here the river route will come in. The railway will feed the river and the river will feed the railway. It will be possible to develop the Siberian mines and to grow Siberian wheat for export. At the present moment the Siberian farmer only sows once in three years, because he has no outlet for his produce, and he wouldn't be much better off if he had only the railway as a means of export."

"Do they thoroughly grasp this in St. Petersburg now?"

"Oh, yes; thoroughly. The Minister of Finance, M. De Witte, said to me the other day, 'Captain Wiggins,' said he, 'the Emperor has asked me what I think of your arguments, and I told him I was quite convinced by them, and we must do everything to make the Yenissei route a success.' And they are really showing a great deal of energy in the matter, for they have already put a lot of steamers on the stream, and they have sent a party of naval officers to do the hydrographic work. In a very few years the Yenissei and its tributaries will be alive with trade reaching right into the heart of Mongolia."

"The Hudson's Bay projects," said Captain Wiggins, recently, to the London Chamber of Commerce, "why the Hudson's Bay, with its paltry little creeks leading to the Winnipeg Lake system, isn't in it by comparison with the country of Siberia, with its noble rivers reaching from the Arctic circle right to the cereal zone. If the rivers running into Hudson's Bay reached as far south as Mexico, there might be a comparison." Captain Wiggins went on to say that the Hudson's Bay Company made their money out of fur and fish; but in the boundless resources of Siberia, a tract of more than 4,000,000 square miles, the finest fur country in the world was but an item. The great Yenissei river, mightier than the mighty Amazon ("I've been to both," the lecturer said parenthetically), passed through the fur country into the forest regions,

which will each take a year to construct. But when it is finished—how gorgeous the prospect! Here is a country rolling in wealth, with a population (so one might almost gather from Captain Wiggins) of millionaires, a country such that the carriage of China goods will almost monopolize the carrying power of the railroad—a country which wants no money to develop it, but only the cheapest kind of labor.

The accompanying sketch represents the early morning experiences of Captain Wiggins' party on their way from Chabarova to Petchora. The party traveled in three sections, being carried by eighty-seven sledges drawn by from three to five reindeer each, and guided by Samoyede men and women. Each night separate encampments were made by the parties as close as possible to some stream where the moss required to feed the reindeer was plentiful. Native tents or chooms were erected for the shelter of the travelers. These tents were twenty feet in diameter, and they were carpeted with deer skins. Every morning at six o'clock, after coffee had been distributed, the tents were taken to pieces. The deer, which had been turned loose overnight, were then driven in by the Samoyedes and their dogs. The hunt generally ranged over a radius of three versts. For the reception of the animals, the travelers formed a broken circle with ropes. A few stragglers were always difficult to catch, and they were hunted in by means of the sledges, from which the Samoyedes whirled their lassoes with unerring effect.

THE "SCAB."

I HAVE felt, as a friend once said, that if I were to lead any crusade to-day, I should want to be the champion of unorganized labor. I have no quarrel with organized labor, but I cannot forget that, while a certain band of laborers is receiving all the sympathy of the public and all the countenance of courts and legislators, there is a great body of workingmen, more needy and far more friendless, whom these privileged "knights of labor" treat only with abuse, and toward whose welfare the community at large seems absolutely indifferent. I cannot forget that there are hundreds of destitute workingmen in our city who are hooted and stoned for the crime of being willing to work. The epithet "scab" has become in my ears a title of honor,

synonymous with pluck and patience. What American heart, unless dulled by long submission to such outrages, can help throbbing with indignation that hundreds of industrious workmen are subjected to violence and peril of their lives, simply because a privileged class of laborers do not choose to have any competitors? For the good name of Brooklyn, let one protest be heard, for this ignoble tyranny cannot but work degradation to the community which submits to it.—From a sermon by Rev. Samuel A. Eliot, of Brooklyn.

EMBARKATION OF SPANISH TROOPS FOR CUBA.

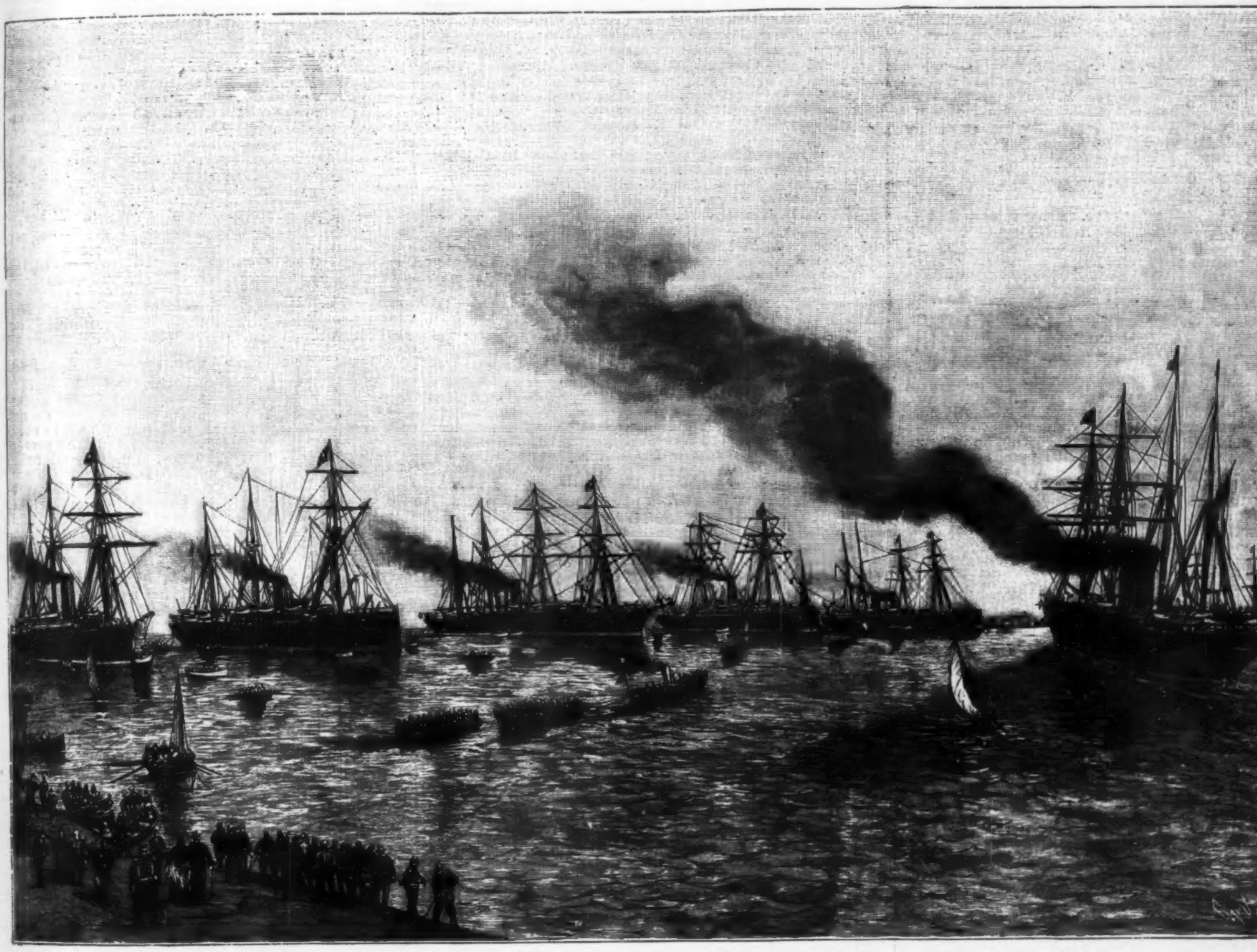
ANOTHER revolution has broken out in the island of Cuba, and judging from the desperate efforts the Spanish government is making for its suppression, the revolt is extensive and may prove successful. The only wonder is that the people of Cuba have not long ago arisen and thrown off the yoke of oppression under which Spain holds them.

The peoples of all the Iberian possessions in this hemisphere, Cuba and a few small islands excepted, have freed themselves from Spanish dominion. Let us hope that the Cubans will follow their example and expel their present unworthy masters, whose only object ever has been, from the date of Columbus' landing in 1492 to the present time, the sacrifice of the natives and the plunder of the country.

The island of Cuba is distant only 130 miles south of Florida. The island is 730 miles long and averages about 80 miles broad, its area being about 47,000 square miles—as large as the State of Pennsylvania. Its soil is rich and everything grows with tropical luxuriance. The exports of sugar alone reach about $65,000,000 per annum, most of which is sent to the United States, and paid for in cash.

La Ilustracion Española, of Madrid, to which we are indebted for our illustration, says that, when the former revolution of 1868 took place in Cuba, there ought to have been a garrison of 20,000 troops on the island, but in fact there were only 5,000. The same state of things now exists, after twelve years' experience and a loss of 130,000 lives (counting Cubans and Spaniards) and a cost of $700,000,000. Our cotemporary thinks that in all history there is no such example of imbecility as this.

To supply the present lack of soldiers, which was urgent (everything is urgent to those unprepared), it was decided to take one battalion from each of the six army corps of the peninsula. These troops were hurried off to Cadiz, and embarked on the steamers of the Transatlantic Compania, and have lately landed in Cuba. Our engraving shows the embarkation and the steam transports.



THE REVOLUTION IN CUBA—EMBARKATION OF SPANISH TROOPS AT CADIZ.

HISTORY AS A SCIENCE.*

By Prof. G. W. PROTHERO.

WHAT place, if any, does history hold among the sciences? The historical student labors under several serious difficulties and is exposed to some peculiar dangers. His first and most obvious difficulty arises from a lack of information. The student of modern history feels this comparatively little; the medievalist feels it more; the student of antiquity, except for a few short periods in the history of Greece and Rome, feels it most of all. But such gaps are not found in history alone. Even astronomy has its dark spots. There are shady spaces, to say the least, in evolutionary biology. There survive only tantalizing fragments of the old Etruscan tongue. Shall we ever know what is on the other side of the moon, or bridge the gulf between organic and inorganic matter? Natural science, it is true, may fairly hope to pursue indefinitely her wonderful career of discovery. Still in every branch of human knowledge there are gaps and gaps—we may be sure there always will be. There is no difference of kind here—only one of degree.

In the second place, the historian cannot employ experiment either to discover facts or to test conclusions. History has one chance of observing a great man, an epoch-making event; if it loses that chance, the loss is probably irreparable. But here, again, history suffers in good company, along with philology and geology, and all the other branches of knowledge which are concerned with the past. A more serious obstacle to the scientific investigation of historical phenomena arises from their infinite variety and from the vastness of their extent. The whole evolution of human society is the province of history. What an immeasurable field! It embraces not political evolution alone, but the history of religion and philosophy, of literature and art, of trade and industry. There is not a side of the multifarious activity of man which the historian can safely neglect, for there is nothing that man thinks or does, or hopes or fears, but leaves its mark on the society in which he lives. And in all this there are no two events, no two men, no two institutions exactly similar. History does not repeat itself.

Lastly, there is the peculiar difficulty which arises from the presence of the human element in the subject under investigation, as well as in the investigator himself. Take any great movement you please—the Crusades, for instance, or the Reformation; analyze it as minutely as possible, ascertain all its conditions, its general causes, its immediate occasions—there remains the incalculable human element, which defies the processes of exact science. We cannot be certain of this man's motives nor measure the influence which that man exerted. The human element in the subject calls out the human element in the student. Not only is the investigation obscured, but the sympathies of the investigator are aroused and his judgment is liable to be warped at every turn. History alone suffers from this doubly distorting medium. Other sciences are free from its effects. It is comparatively easy to be impartial about the theory of light or the behavior of a comet, but few of us can discuss Edward the First or Mary Stuart and keep our heads quite cool.

These are obstacles which, it must be allowed, check history on the threshold of science. But all sciences are not equally exact or equally capable of generalization. The theory of gravitation is, I presume, better established than that of natural selection, but biology is none the less a science. The law of rent and the law of diminishing returns are not exact—they are qualitative rather than quantitative. The economist cannot foretell in pounds, shillings and pence the results of a new gold mine in Australia or a disastrous harvest in the United States. But for all that, political economy is recognized as a science. There is, in fact, a regular gradation, from the sciences of abstract reason and mathematical formulæ, through the phenomena of the inanimate and the animate world to the world of man. In proportion as life and its accidents play a less or greater part, knowledge becomes less exact, less scientific. And inasmuch as the phenomena of history are more various and complicated, less capable of complete analysis, more deeply permeated by the incalculable human element than other classes of phenomena, history must, if we look only to exactitude and general laws, give precedence to other branches of knowledge. Thus much every candid student of history will allow.

But what follows? Surely not that history is in no sense scientific—that to distinguish scientific from unscientific history is merely to play with words. In the first place, history can be scientific in the ascertainment of its facts. Of the facts of history a vast number are established beyond the possibility of doubt, if anything in this world is indubitable. Some persons may think that Shakespere is merely a nom de plume for Bacon, but no one doubts that there was a battle of Marathon and a battle of Waterloo, and that these events led to certain obvious results. But all historical facts are not equally sure. Between the degree of certainty attainable respecting such facts as these and that attainable respecting, let us say the Volkerwanderung or the black death, there is obviously a large interval.

But to ascertain facts is only one part of the functions of an historian. From these established facts he must draw trustworthy conclusions. He must not only state, but reason. And neither part of his work can

* An inaugural lecture delivered at Edinburgh University, on October 16, 1894, and printed in the National Review, London.

stand alone. The really great historian, the Gibbon or the Ranke, possesses both qualifications.

There is, then, I repeat, a scientific way, as there is an unscientific way, of studying history. If treated one way, its results are guess work and delusion; if treated another way, if industry, reason, and sober judgment are brought to bear, its results are in many cases matter of certainty, in many others matter of at least high probability. And if we except the science of mathematics, what more can be said of any science?

[FROM THE AMERICAN NATURALIST.]

OBSERVATIONS ON A SO-CALLED PETRIFIED MAN.

By J. M. STEDMAN.*

WITH A REPORT ON THE CHEMICAL ANALYSIS.

By J. T. ANDERSON.†

ON the 28th day of August, 1894, a human so-called petrified body was found by some workmen while repairing a public country road about one mile south of Tuskegee, Macon County, Alabama. A few days later I heard of the find and immediately proceeded to Tuskegee to make an investigation of the body and of the locality where it was found, and to obtain samples of the water, earth and body.

Through the kindness of Mr. J. S. Webb, who had the body in charge, I was enabled to make an examination on and to procure portions of the body from the several places as samples. As Mr. Webb was trying to sell the body as a curiosity, he did not wish me to mutilate it any more than was necessary. I obtained, however, portions of the intestine, a section 75 × 25 mm. through the ventral abdominal wall, several pieces of muscle with tendon from the ankle, and a section 100 × 100 mm. was cut out from the dorsal region of the thigh and extending to the bone in thickness. Mr. Webb, by the way, offered me the body for the college museum for $75, but, as I hoped to be able to procure it later as a donation, I refused. He sold the body in a few days for $150, and it is now being exhibited in the villages and cities of the country, much to my regret.

The body is that of a negro woman who was evidently rather fat. From two elderly gentlemen, who are now living in Tuskegee, and who remember the circumstances of the burial, I learned that the body was buried in 1837 in what was then a small, neglected country or family burying ground, situated a few rods from the road. They also remember the burial, at about the same time, of an Indian but a few feet from this negro; and I am trying to have the Indian dug up to ascertain whether it is likewise preserved or not.

In company with several citizens of Tuskegee I drove to the scene of the find. The burial ground is near the top of a very large flat hill or plateau, and a few rods south of the grave is a small marshy or swampy bog, while some seven meters to the east there is a spring. Several years ago the public road was moved a few rods to the south in order to give it a better grade up the hill, and as the small, neglected burial ground had not been and was not worth keeping up, and was no longer used as such, the road was cut through a portion of it; and most people had now forgotten about its existence. The road was cut about one meter below the surface, and the ditch at the side was directly over the negro woman's body, and served to carry off the water from the spring just above. The result was that the body lay but about one-third of a meter below the ditch, and the water from the spring kept it continually wet, even when no water appeared on the surface. While the workmen were repairing the road and picking in the ditch, they hit something that proved to be a pine board. On removing it they came upon others, which they removed, and thus exposed a plain pine coffin in a remarkable state of preservation.

The soil where the body was found is sandy, with enough fine, light colored clay and moisture to give it the appearance of mortar. When a portion of the soil was dried, it held together with great tenacity, and the dirt left on one's hands became nearly white on drying, and felt smooth and slippery like powdered talc; in fact, I could detect no difference as regards looks or feeling. Portions of the soil had streaks of red color, probably due to iron. The hole left by the removal of the coffin soon filled with water, the soil being extremely wet, although very little moisture appeared on the surface on account of excessive dry weather. The water had a decided milky appearance. I obtained samples of the soil from the bottom of the hole, from the sides, and from the earth just above; and also samples of the water from the hole. These were placed in thoroughly clean jars brought for the purpose.

The first thing to be noted is the fact that the boards that covered the coffin, as well as the coffin itself, were in a perfect state of preservation—not a sign of decay was to be found. They looked like newly planed boards that had been exposed to the weather for about six months; just long enough to partially color the wood gray. The nails in the coffin had all rusted away.

On opening the coffin, the body of the negro woman was found to be in a remarkably good state of preservation. Of course it was saturated with water, but, nevertheless, it was firm like hard cheese, so that the workmen pronounced it petrified when they touched it, and found it would not give or bend. In general, the body at first glance has very much the appearance of sheet asbestos, being dirty white in color, with a certain grain in places, due to the connective tissue in the fat where the skin is wanting. The abdomen and to a certain extent the thorax is swollen and bloated, so that part of the abdomen pressed tight against the top of the coffin, thus showing that decomposition had started when the body was first buried, and had continued for a short time. It is to be noted that no part of the body was decomposing when found, and it has shown no signs of doing so since; neither does it smell—all decomposition that had taken place was now checked. The head is not well preserved, part of the cranium having been decomposed, and other parts partially so, and more or less separated. All the hair, with part of the scalp, is, however, well preserved, while the face had been partially decomposed. One wrist and both ankles had been badly decomposed, and part of the feet and one hand slightly decayed. Some of the toe and finger nails were perfect, others partially or wholly decayed. The rest of the body is practically intact and well preserved, except that in places the skin is wanting; but this does not make itself apparent to the ordinary observer.

With a scalpel I cut through the ventral abdominal wall from right to left, and then cephalad at the two ends. The body at this place cuts very much like dense cheese. The cut portion was then lifted up and turned back, thus exposing the viscera beneath. The intestines, and in fact all the viscera, were only partially preserved. They had become more or less decomposed, and had then been checked in their decomposition and preserved in that state from further change. There was no particular smell from the abdominal cavity, and no decomposition was in progress. The intestines were moist, loose and pliable, and the fæces still preserved in them. All the viscera were light in color, due to the partial deposition in them of the finely suspended, and perhaps more or less soluble, mineral matter in the water that filled and covered the body. The deposit of this mineral matter was not in sufficient quantity to give the tissue much firmness.

The abdominal wall which was cut through in order to examine the viscera was 30 mm. thick, and owed its dense, cheese-like consistency and firmness to the deposition in it of the finely suspended mineral matter contained in the water that constantly saturated the body. The abdominal wall was practically completely charged with the mineral matter, while the process of filling the viscera had but nicely commenced. The mineral matter was extremely fine and of a light or almost white color, and thus it was that the body appeared light. So far as I was able to determine, this mineral matter in the tissues of the body is the same as that held in suspension in the water, and which gave it the milky appearance; and also that which in the soil or sand gave it the appearance of mortar, and that when dry, looked and felt exactly like powdered talc. With the exception of the fat, the tissues of the abdominal wall were practically intact, the mineral matter simply saturating them and filling up all the spaces; in the fatty tissue, however, which composed a large part of the abdominal wall at this point, there had been more or less substitution of the mineral matter for the fat. This substitution was, roughly speaking, about half and half. Hence it was that where the skin was wanting, there appeared a grain, due to the connective tissue remaining, while the fat was partially substituted. Wherever the skin was preserved, the black pigment could be distinctly seen in a cross section.

In cutting and then removing the 100×100 mm. piece from the back of the thigh, I was surprised to find that the deposition of mineral matter had taken place to the extent of 25 mm. in depth, and that from this point inward the muscular, connective and other tissues were in such a perfect state of preservation that they looked and felt exactly like fresh cornbeef. The flesh of muscle was of dark red color, and of a perfectly natural and fresh consistency, showing no signs whatever of having undergone the slightest decomposition; it did not emit any more odor than fresh meat. The perimyseum appeared perfectly natural, the tendons glistened as well as the perimyseum near them, and the connective tissue was, to all appearances, as strong and well preserved as one could expect to find it in a body dead but twenty-four hours. On teasing the muscles, the fasciculi held together perfectly naturally, and the only difference besides color that I could then detect between this muscle and a perfectly fresh one was that this appeared to have a little more firmness, but it was very slight, and if compared with fresh cornbeef this difference disappears. It is also to be noted that the external layer, averaging 25 mm. in thickness, where the deposit and substitution of mineral matter had taken place so completely, and which covered the entire body and gave it its consistency, that this region was quite sharply marked off from the region below. In other words, the deposition and substitution of mineral matter had taken place to the extent of about 25 to 30 mm. in depth all over the body (wherever examined it was of this depth), and rendered this portion very dense, tough and firm; and, instead of gradually merging into the soft almost unchanged inner portion, the change was quite abrupt. From an examination of the abdominal wall, I at first supposed this abrupt and sudden change to indicate and be due to the region of fatty tissue, but I found, on further examination, that the abrupt change took place in the muscular tissues of the thigh, where little or no fat was to be found.

On reaching my laboratory, I made a microscopical examination of the samples of tissue by means of sections and teased preparations, in order to determine the extent of the preservation of the histological structures. I found that the skin was nearly substituted by mineral matter in most places, and in some wholly substituted. The fatty tissue was also substituted by mineral matter to the extent of about 50 per cent. The muscular tissue, where the deposit of mineral matter was greatest, did not seem to have been replaced to any considerable extent, but was simply saturated with the deposit. Where the muscles were still soft, the fasciculi, and even the fiber cells with their striæ, were remarkably well preserved and easily demonstrated. The perimyseum and tendons were practically perfect. The connective tissue was surprisingly perfect, the only change being the loss of the connective tissue corpuscles in many places; but even these were found in the better preserved soft muscular tissue. The nerves were not well preserved histologically. The blood vessels in the soft muscles were fairly well preserved; the blood corpuscles were not to be found. The periosteum and the bone were perfect, except in those regions like the head and ankles where decomposition had taken place.

I then examined, by the agar-agar plate culture method, the muscular tissue for bacteria, and found none. The water taken from the hole, left by the removal of the coffin, also failed to reveal the presence of bacteria on an agar-agar plate culture of 1 c. c. of the water.

A piece of the soft muscular tissue from the thigh was then placed in a museum jar of water from the grave. This jar was opened every few days for more than a month, and the muscle taken out to show it to visitors. The water, jar or muscle had not been sterilized; no caution was taken, in opening the jar, to close it for some minutes, nor to protect the piece of flesh. I did this in order to determine how long it would keep under those conditions, and I therefore watched it and made examinations from time to time. To my surprise, the piece of muscle is this day, the 15th of December, 1894, of a reddish color and looks quite natural, but I now find, on examination, that it is becoming softer, and that bacteria have made their appearance, so that the tissue will ultimately decompose.* It was this test that I wished to finish that prevented me from publishing this article just as soon as the chemical analysis was completed.

The large piece cut from the thigh was placed in an empty museum jar in order to keep it as moist and natural as possible, and to observe how long it would thus resist decomposition. The piece was frequently taken out of the jar to allow visitors to examine it. I found, in about two weeks, that a small mould was making its appearance on the surface, and I then cut it in halves and placed one in alcohol and the other on my table and allowed it to dry. Of course the specimen in alcohol is preserved, although it does not look natural; it has become darker colored and the flesh has shrunken and become harder, while the hard external region of greatest deposition of mineral matter has become much softer. The specimen exposed on the table dried in a few days with the usual changes, and is now preserved in that state, and shows no signs of moulding or decaying. The entire body is now dry, and will keep, no doubt, indefinitely in that condition.

Of course the greatest interest attaches itself to the question of the cause that checked decay and preserved this body for fifty-seven years, with the certainty, I might say, of doing so indefinitely, and, perhaps, of ultimately converting it into a hard fossil by substitution. It was with this object in view that I obtained samples of the water and earth from the grave and gave them to Dr. Anderson for chemical analysis, and also portions of the body itself for chemical analysis. And now that the analysis of all these has been made, I must confess I do not see my way clear. I cannot understand why decomposition should not have continued on the inside until the viscera and muscles were obliterated. The body seems to have acted like a filter, and to have taken out and held in itself the finely suspended, and perhaps also some soluble mineral substances in the water. This filtration naturally saturated the external layers of tissue first, and, when found, had not extended far inside.

I think I can understand, then, why it is that the external tissues are preserved, but I do not understand the preservation of the inner tissues. I do not believe that the small amount of lead found in some portions of the body itself can account for the preservation. Can it be that the silica, alumina and oxide of iron held in suspension, and the silica, lime and magnesia in solution in the water, could have prevented decomposition? The three ingredients, silica, alumina and magnesia, constituted the bulk of the mineral substances deposited in the tissues, and that near the periphery was in sufficient quantities to give it a firm consistency. The soil contained nearly 3 per cent. soluble silica, and the water contained a large percentage; but can this account for the preservation? The observed fact is that the body was preserved and decay completely checked, and I can only account for it by saying that the combined action of all the ingredients of the water—silica in suspension and in solution, alumina and oxide of iron in suspension, and lime and magnesia in solution—is to be looked upon as the cause.

And what is still more obscure is the fact that the body was buried with a shroud (or some clothes), while all that now remains of it is the imprint nicely stamped on that part of the abdomen that had swollen and pressed closely against the lid of the coffin, and also on the lid of the coffin where some of the mineral matter is adhering. Every thread of the cloth is as plainly visible in the impression as it is possible to make them with plaster casts. It appears to have been a cotton sheet, but not a fiber of the original cloth is to be found. Now, why was this cloth not preserved? If it was cotton cloth, its chemical composition was practically the same as that of the pine coffin which was perfectly preserved; if the cloth was woolen (there can be but little doubt that it was cotton), its chemical composition was practically that of the hair, which was also perfectly preserved. I cannot account for this to my own satisfaction, and will offer no suggestions; to me this is more difficult of explanation than the preservation of the body.

Through the kindness of Dr. Anderson, first assistant chemist on the Experiment Station, who made the chemical analysis of the water, soil, and body, I am enabled to submit herewith his report on the same:

With a view of determining the agency by which the body was kept in so excellent a state of preservation, the soil in which the body was buried, the water which percolates through the soil from the spring above, and the flesh from the body itself were all subjected to chemical analysis.

The soil presents no peculiarity in its composition further than it is a highly silicious soil. It contains 95·91 per cent. of insoluble residue and 2·94 per cent. of soluble silica, thus giving nearly 99 per cent. of silicious matter. Next in importance as regards quantity comes alumina and oxide of iron—nearly 1 per cent.—and then lime, magnesia, and the alkalies in minute quantities.

When found the coffin containing the body was submerged in water, and when the coffin was removed the hole soon filled with water. A sample of this water was taken for analysis. After remaining in the bottle undisturbed for four or five weeks, a considerable sediment, chiefly of sand, formed in the bottom, but the supernatant liquid remained decidedly milky in appearance. The suspended matter which caused this milkiness was found to be silica and alumina, with

* Professor of Biology in Alabama Polytechnic Institute, and Biologist of Experiment Station.

† First Assistant Chemist of Experiment Station.

* Since writing the above the proof has just reached me (11th of March, 1895), and as nearly three months have elapsed since the observation was made, it may be of interest to note that I have kept the sample of flesh on my desk ever since, and that it is to-day only partially decayed.

oxide of iron. The water presented no other peculiarity, but contained lime and magnesia.

Naturally, the chief interest attaches to the chemical examination of the flesh itself. To preserve the specimen in the condition in which it was found, it was kept in a bottle with a ground glass stopper. Determinations were made of water, fat, organic matter other than fat, and ash. From a number of determinations the following averages are taken: Water, 55 per cent.; organic matter, 44 per cent., 32 per cent. of which was fat; and ash, 1·23 per cent. The least amount of mineral matter found was 0·33 per cent. and the largest 2·10 per cent. It was found to contain silica, alumina, oxide of iron, lime, and magnesia. But, in my estimation, the most important find was lead. This was not found uniformly distributed throughout the specimen. From two to three grammes of the flesh were used in each determination. In two of these samples not a trace of lead could be found; in three or four others a perceptible quantity was obtained, while in one a sufficient quantity was got to make a metallic bead. There can be no doubt, therefore, that lead in some form exists in the body. It was found in a part of the specimen which had been kept several weeks in alcohol, and hence must have been incorporated with the tissues of the body.

Whether lead was the sole agency in the preservation from decay I cannot say; but that it exerts an influence in that direction cannot, I think, be doubted. It is recorded that a solution of sugar of lead, among other things, was used as an embalming fluid during the civil war. It is hardly probable that the body in question was embalmed, as it is that of a negro; but some salt of lead may have been administered as a medicine. It is well known that lead is a "cumulative" in its nature—that is, when taken into the system from time to time, even in small quantities, it is not thrown off as is usual, but is retained in the system and thereby accumulates. May not the presence of lead in the body under examination be accounted for in this way? It is a matter of regret that reliable facts relating to the history of the case before us are unattainable.

ON THE NATURE OF MUSCULAR CONTRACTION.*

THE subject of this lecture is an inquiry into "The Nature of Muscular Contraction." Like all vital phenomena, muscular contraction is a most complicated process, composed of mechanical, chemical, thermal, and electrical changes in living matter. Hence it will be our task to become acquainted with these changes as completely and exactly as possible, and to ascertain their causal connection. Our inquiry must not be restricted to one special kind of muscle; it will have to extend to all the different forms, for there can be no doubt but that in all these cases the principle of activity is the same. Nay, it will be necessary to deal even with the other phenomena of so-called contractility, such as protoplasmic and ciliary motion, for all these different types of organic movement, however much they may differ from each other in details, are yet so connected by gradual transitions that to all appearance one principle of motion, essentially the same, is applicable to all of them.

The general mechanical principle on which muscular contraction is based will be discovered when we shall have ascertained in what way the power of shortening proceeds from the potential chemical energy which disappears upon stimulation of the muscle.

There can be no doubt as to the fact that the potential chemical energy of the component parts of muscular substance is alone the ultimate source of this power, for the existence of any other source cannot be proved. The quantity of energy which is imparted to the muscle by the stimulus is too small to be taken into consideration. The early opinion that the power required for contraction was imparted to the muscle through the medium of motor nerves has been refuted by experiments, such as, e. g., on the persistence of contractility after degeneration of the motor nerves, and on the effects of direct artificial simulation of the muscles; and it had even been refuted long ere the law of conservation of energy had thrown its light on the mutual connection between the phenomena of the living organs.

This law teaches that all the actual energy which appears in the muscle in consequence of stimulation must originate in an equivalent quantity of some other form of energy.

Now this form of energy is, in fact, given in the muscular substance liable to physiological combustion. The quantity of the latter is not only theoretically sufficient to produce that actual energy, but it has even been proved experimentally that during contraction that material gives birth to combinations such as carbonic acid, in the development of which potential chemical energy must have passed into other forms of energy. As far as the phenomena have been examined quantitatively, they confirm the conclusion that all muscular force must be derived from chemical energy.

Hence there is no difference about all these points. But with this result we have as yet gained only a basis for the proper solution. So soon as you inquire in what way, by what transformations, does the mechanical force of contraction arise from chemical energy, difficulties and differences of opinion begin to present themselves.

A great many physiologists hold with Pflüger, Fick, and Chauveau, that muscular force is a direct manifestation of chemical attraction; others, e. g., Solvay, think that it is produced through the medium of electricity; others again, following J. R. Mayer, believe that the muscle is a thermodynamic machine, not unlike our caloric or steam engines.

The Chemiodynamic Hypothesis.—The first hypothesis, according to which contraction of muscle is a direct manifestation of chemical attraction—we may call it the chemiodynamic hypothesis—has to assume that the molecules, on the chemical combination of which this contraction is based, are regularly arranged within the contractile substance in such a way as to make them approach each other at their combination in the direction of the axis of the muscular fibers.

I think that this hypothesis of the identity of chemical attraction and muscular force meets with a fundamental difficulty in the fact that, in a single contraction, only a relatively infinitesimal part of the muscular substance is chemically active; 70 to 80 per cent. of the muscle (and even more) consists of absorbed water, the rest contains substances (albumen, salts, etc.) which, for the greater part, so far as can be proved, are not chemically concerned in the contraction.

This quantitative composition and this minute consumption of the active muscle compel us to assume that relatively only very few molecules of the muscular substance can be considered as sources of energy, and of these again it is generally but a small part that at a certain moment perform their function.

With certain presuppositions we may calculate the quantity of matter through the chemical action of which the amount of actual energy, produced at a certain contraction, must have been generated.

If we prevent a muscle from doing external work during the contraction, the whole actual energy will present itself in the shape of heat. When there is but a slight contraction, the muscle of a frog, e. g., will grow warmer by about 0·001° C. Supposing the specific heat of the muscle to be equal to that of water (in fact it is less), we find that for a rise of 0·001° C. in temperature a quantity of heat of 0·001 cal. is required for each gramme of muscle. No matter whether this quantity of heat results from the combustion of carbohydrates, fats, or albuminous matter, it can be but an infinitesimal part of the muscular substance that produced it. If, e. g., as is ordinarily supposed, the combustion of a carbohydrate into CO_2 and H_2O produced that heat, taking the heat of combustion of one gramme of carbohydrate to be broadly 4,000 cal., no more than a four-thousandth part of a milligramme will have been consumed in each gramme of the muscle. Hence only about a four-millionth part of the muscular substance could have been the source of the actual energy set free by the stimulus, and at the same time, according to the above hypothesis, have been the subject of direct attraction.

But whatever may be our conception of the size, form, position, and sphere of action of this four-millionth part in relation to the other soft, watery mass, only passively moved, I fail to understand how, through direct chemical attraction, this one minute part should bring about the movement of the rest of the four million parts in such a manner as it does.

The adherents of the chemico-dynamic hypothesis have not answered this objection as yet. And since they can give but an unsatisfactory account or no account at all of many other facts (I will refer to some of these facts further on), we may be allowed to cast about for some other explanation.

The Electrodynamic Hypothesis.—Since Galvani's discoveries, the electric phenomena of muscles have frequently been suspected to contain the solution of our problem. And, indeed, it is not so very difficult to mention a series of facts which seem to bear out the suggestion that the mechanical work done by the muscle may be created from chemical energy through the medium of electric forces.

There is, in the first place, the fact that muscles, when in action, produce regular electric effects. These effects are indeed the first phenomena we can observe after stimulation. They seem to begin at the very moment of stimulation, shortly before the contraction; hence they might in so far be the cause of the mechanical process.

Moreover, as Du Bois-Reymond proved, the value of the electromotor force is very high, and in the active particles is probably much higher than the force of the currents we can derive from the surface of the muscle.

Add to this that the economic coefficient of the muscle may attain, just as in the case of electric motors, a considerable proportion. As much as 25 per cent. and more of the potential energy which has been consumed may be transformed into mechanical work.

However, there are weighty objections to this hypothesis also. In the first place, there is the fact that these very same electromotor forces, of equal intensity and direction, appear, under the same influences, not only in the muscles, but also in nerves, glands, and other organs, which do not possess the least contractility. Then there is the important discovery of Biedermann, that the contractility of muscles may be completely neutralized by water or etheric vapors, without doing any perceptible harm to the electromotor phenomena.

In the same way the development of the electric organs supplies us with important proofs of the independence of the electric and the mechanical processes. In most cases these organs are developed out of striped muscular fibers. Now, in this process of development, contractility is gradually lost, whereas the power of producing electrical effects attains a yet higher degree of perfection.

The Thermodynamic Hypothesis.—More probable than the chemical and the electrical hypothesis may be deemed a suggestion, first put forward by Jul. Rob. Mayer, though in an untenable form, according to which the muscle is a thermodynamic machine. Physiologists, however, generally object that this view is not compatible with the second law of thermodynamics, for we cannot expect differences in temperature in the muscle so great as this law requires they should be.

Now I venture to think that, on the contrary, we must assume exceedingly great differences of temperature in the stimulated muscle. What holds good of the whole body holds good of the muscle also; the temperature, measured with our instruments, is but an arithmetical average, "comprising an infinite number of different temperatures, pertaining to an infinite number of different points" (Pflueger).

From the fact that at the contraction an infinitesimal part only of the muscular mass is chemically active, we infer that the temperature of these particles must, at the moment of combustion, be an uncommonly high one. Great as the specific heat of muscular substance is, it would otherwise be impossible to account for a rise in the temperature of the whole mass even of 0·001° C. only.

Since each thermogenic particle is surrounded by a relatively enormous cool mass, conducting heat and diathermanous, the principal condition for the transformation of heat into mechanical work has been satisfied, and, on account of the enormous differences in temperature which we have to assume, satisfied to such a high degree that even an economic coefficient of 30 per cent., nay, 50 per cent., and even more, seems to be theoretically possible.

Supposing we have to deal with a Carnot's cycle, the theoretical maximum Q_a of the mechanical effect is

$$Q_a = Q\frac{T_1 - T_2}{T_1},$$

where Q stands for the whole quantity of heat, which, from the absolute temperature T_1, is sinking down as far as T_2. Taking $T_2 = 273° + 37° = 310°$, the mechanical effect might at $T_1 = 410°$ amount to 30 per cent., when the temperature of the active particles would consequently exceed the average temperature of the normal muscle by 100° C. only.

The objection that these high temperatures must necessarily destroy the life of the muscle, since the latter becomes rigid and dies even at 50° C., is, for the same reasons, of small importance only. For it is ever but an infinitesimal part of the muscular mass that is exposed to these high temperatures. At a small distance from these furnaces of heat the temperature must have fallen so low as to be harmless. The muscle will no more be destroyed by stimulation than a steamer will be destroyed by heating the furnaces.

However likely it may thus seem that nature should avail herself of these favorable terms on which mechanical work may result from muscular heat, we have up to the present time no direct proof that this is actually the case, nor do we know in what way it takes place, if in any. But I venture to think that the proof can now be given, inasmuch as it is possible to demonstrate how, through the medium of peculiar arrangements of the material of the muscle, a transformation of chemical energy into mechanical work by means of heat not only can, but actually must, be brought about.*

MUSCULAR STRUCTURE IN RELATION TO CONTRACTILITY.

The Fibrils are the Seat of the Shortening Power.—For this we need, first, to pay attention to the peculiarities of the microscopical structure of muscle. All muscular fibers of all animals are composed chiefly of two parts: extremely thin, long, albuminous fibrils and an interfibrillar plasmatic substance, the so-called sarcoplasma. The quantitative relations of both vary, but the fibrils always occur in great number, forming very often the greatest part of the whole mass of the muscle. They always run parallel to each other throughout the length of the fibers.

This fibrillar structure is also presented by all the other formed contractile substances.

Direct microscopical observation during life teaches us that the fibrils, and not the sarcoplasm, are the seat of the shortening power. The fibrils in a state of relaxation are long and thin, and often run in winding curves, but grow short, thick and straight in consequence of stimulation. The sarcoplasm passively follows their movements. Moreover, completely isolated fibrils can shorten.

The Fibrils are Contractile, Because they Contain Doubly-refractive Particles.—Thus the question arises: Can there be demonstrated in the fibrils such arrangements of their material as by their mediation contractile force may originate in a thermodynamic way?

Light—lux optimum reagens, as Buys Ballot said—solves this question for us. If we examine the optic properties of contractile fibrils, with the aid of the polarizing microscope, we find that all of them are double-refractive, with one optical axis parallel to the direction of contraction.

This general occurrence of double-refracting power is the more indicative of relations to contractility, since non-contractile cells, as a rule, lack double refraction, even where we meet with a fibrillar structure, as in the axis cylinder of a nerve fiber.

Our conjecture gains, I believe, a very high degree of probability by the following series of observations.

In the first place, the fact that contractility and double refraction in the course of ontogenesis always appear at the same time, e. g., in the heart of the chick, on the second day of incubation; in the muscles of the trunk and skin on the fifth or sixth day; in the muscles of the tails of tadpoles when the length of their body is 3 to 4 mm.; in the muscles of the stalk of Vorticella, and in cilia so soon as these organs become visible.

Another evidence seems to me to be afforded by the behavior of the striated muscles. Here the fibrils consist of the doublyre-fractive sarcous elements and the singly-refractive material which joins these, the two alternating regularly. The two are wholly different as regards their optical, mechanical, and chemical properties; and these properties, moreover, during contraction, change in an opposite way. Hence the functions of the two must be of a different kind. And since the changes of form, volume, etc., of the doubly-refractive parts during contraction prove that in each case these parts must be the seat of contractile power, the single-refractive junctions will most probably have another function. We will come back to these changes further on.

A third evidence is afforded by the observation that the specific force of contraction in different muscles is, in general, greater, the better developed the power of double refraction, comparison, of course, in each respect being made with parts of the same thickness.

In the development of the pseudo-electric organs of Raja out of striated muscular fibers, one of the signs of the incipient change of structure and function is the vanishing of double refraction in the sarcous elements. In an early stage of development this vanishing is, with Raja clavata, the very first and the only sign that the fiber is about to be transformed from a contractile into an electric organ.

But particularly significant seems to me to be the behavior of the obliquely striated muscles of mollusks and other invertebrata. Here the doubly-refractive fibrils do not run parallel to the axis of the fiber, but describe spiral lines round it; and during a contraction the steepness of the curves decreases, so that the angle

* The Croonian Lecture, delivered by Prof. Th. W. Engelmann, at the Royal Society, on March 14.—Nature.

* The empirical foundations of the views developed in this lecture will be found in "Versuche uber Aenderungen der Form und der elastischen Krafte doppelbrechender Gewebselemente unter chemischen und thermischen Einflussen," in the Appendix of my Memoir, "Ueber den Ursprung der Muskelkraft" (2te Auflage. Leipzig, 1893, S. 54-60), and in the literature cited in the same paper.

formed by the longitudinal axis of the fibril and the longitudinal axis of the fiber may increase from 5° in in the relaxed state to 60°, and even more, in a state of powerful contraction. But the optic axis of the fibril, instead of assuming, in this case, a more oblique position also, as might be expected on morphological grounds, remains parallel to the longitudinal axis of the fiber, and consequently to the direction of shortening of the fiber. Hence it is not the morphological axis of the fibrils, but the optical axis of their doubly-refractive constituents, which coincides with the direction of the contracting force.

Contractility a General Property of Doubly-Refractive Bodies.—More than a score of years ago I pointed out the fact that even non-muscular elements, elements not possessing irritability in the physiological sense of the word, nay, even lifeless, unorganized elements which are uniaxial doubly refractive, may under certain influences contract in the direction of the optical axis, all thickening at one time, and contracting with a force and quickness and to an extent rivaling that of muscles, if not surpassing it. Instances of this are the fibrils of the connective tissue, of the tendons, and of the cornea, and others. The same contractile power was found by Von Ebner in a great many other doubly-refractive histological elements, nay, even in substances capable of absorption and thereby made doubly refractive, e. g., dried colloid membranes; and finally by Hermann in fibrils of fibrin.

I have in this way shown that singly refractive, or only feebly doubly-refractive histological elements, such as the fibers of elastic tissue, obtain, in the same way as caoutchouc, the power, when made doubly refractive by extension, of contracting under certain influences, and further that the force of shortening will generally be greater in proportion to the amount of the double refraction thus artificially produced.

Since, according to Mitscherlich's discovery, similar changes of form may be observed in doubly refractive crystals, we have apparently to deal with a property pertaining to all doubly refractive bodies as such.

Heat as a General Cause of Contraction of Doubly Refractive Elements.—Now, the influence which in all these cases is able to evoke the mechanical energy of shortening is elevation of temperature. Refrigeration has the opposite effect.

Particularly instructive is the thermal contraction of the fibrillar connective tissue, on account of its similarity to muscular movement, even with regard to details.

In tendons and many membranes the fibrils, as well as those of most muscles, are arranged in bundles, all, or nearly all, parallel to each other. For this reason such objects are extremely well fitted for a closer examination of the phenomena of movement. The most suitable material I know is furnished by the catgut strings of violins, which chiefly consist of such bundles, running in steep spiral lines, round the longitudinal axis of the string. They are distinguished from the greater number of naturally occurring objects by their very regular cylindrical shape and their elasticity. On these properties is based their suitability for musical purposes, especially for the so-called "perfect fifth" ("Quintenreinheit").

The Muscle Model.—With the aid of such a string we can compose a model which in a simple way explains how in the muscle mechanical energy of contraction may result from heat without any perceptible rise of the average temperature of the muscle.

A piece of an E string of a violin, about 5 cm. long and previously swollen in water, is fastened to the end of the short rigid arm of a steel rod, while the upper end of the string is fixed to the shorter arm of a lever, turning round a horizontal axis.

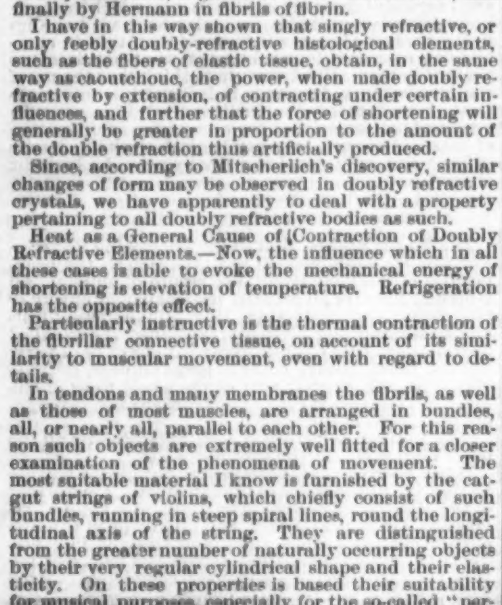


FIG. 1.

To this string different tensions may be imparted by weights or springs, acting upon the lever.

Round the string, but without touching it, runs for a length of about 30 mm., and in about twenty curves, a spiral of thin platinum wire. The ends of this may be connected with the two poles of a Grove or a Bunsen battery of three or more cells. The rod, bearing the lever string and spiral wire, is placed in a glass of about 50 c.c. contents filled with water of about 55-60° C., and closed at the top by an ebonite lid. Through an aperture in the lid, a thermometer is placed in the water in such a position that it will remain at a distance of about 1 cm. from the spiral wire.

The string is now observed for some minutes at a tension of 25 or 50 grammes and at a constant temperature until no further change in the position of the lever can be discerned. If we now close for some seconds the circuit of the battery through the spiral, the lever rises. Upon opening the circuit, it falls. The thermometer in the glass indicates a hardly perceptible rise in temperature, or no rise at all.

We see the doubly refractive string of our model corresponds to the doubly refractive muscular particle, which we suppose to be the seat of the force of contraction, and therefore may be called "inotagma;" the water in the glass represents the watery isotropic substance round the inotagma, doing duty as refrigerant; the spiral wire supplies the place of the chemically active thermogenic molecules; the closure of the galvanic circuit corresponds with the process of the stimulation of the muscular element.

The movements may be inscribed on a rotating cylinder. We then obtain curves of the same character as contraction curves of muscles.

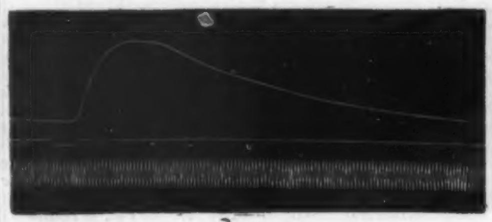


FIG. 2.

Such a chordogram presents, like a myogram, three periods, viz.:

(1) A period of latent energy, the duration of which, just as with the muscle, decreases with the increasing energy of the stimulus (i. e., with the intensity and duration of the electric current), with rising temperature and with decreasing load.

(2) A period of augmenting energy, in which contraction takes place with a rapidity, first increasing, afterward diminishing, the contraction being, within certain limits, more rapid and the larger in extent the stronger the stimulation.

(3) A period of declining energy, in which the string relaxes with a gradually decreasing rapidity.

Further Comparative Researches on the Thermal Contraction of Lifeless Double Refractive Bodies and the Physiological Contraction of Muscle.—The points of resemblance between our model and a muscle extend much further yet, and among other points to peculiarities which seem to bear important testimony to the identity of the mechanical process in the two cases.

Such a resemblance I find, in the first place, in the fact that the strength of the shortening power, developed by a certain stimulus, increases with the load within certain limits. Both muscle and string present the paradoxical phenomenon that, under a stimulus of equal energy, heavier weights may be lifted higher than lighter ones.

Neither the chemical nor the electrical hypothesis of the origin of muscular force can give a sufficient explanation of this fact. On the basis of our theory, on the contrary, it can be predicted, because every influence which augments the doubly refractive power must raise the power of contraction.

Now, Von Ebner has proved experimentally that the force of double refraction of tendons and also, between certain limits, of muscles, increases with the load. The same is the case with fibers of elastic tissue and with caoutchouc, and with these also the contractile power increases with the load. The differences of force thus depending on the load are by no means insignificant.

Connected with this point is another fact, viz., that the force of shortening produced in our model by means of a given rise of temperature is the smaller the more the string has already contracted. The maximum of force is, at all events, displayed when the extension of the string is brought by the whole load being applied at once at the very beginning of the heating, not after the string has already contracted with a smaller load.

The very same thing, as Schwann's experiments showed many years ago, holds good of muscle. On the hypothesis of chemical attraction we should decidedly expect the reverse; viz.: increase of force with an increasing mutual approach of the combining molecules; so also in the same way on every other hypothesis which pronounces contraction to be caused by attractive powers increasing in inverse proportion to the square of distance.

In the fact discovered by Schwann, Johannes Muller thought he had found a refutation of the old electrodynamic hypothesis of Prevost and Dumas, as well as a valid reason for assuming a fundamental relation between the vital power of contraction and physical elasticity.

However, as Hermann has observed, we might in this case get over the difficulty by supposing that between or in the length of the parts attracting each other there are elastic layers opposing that attraction with increasing force. It is evident that our view of the matter does not require such an auxiliary hypothesis, because, in accordance with Eduard Weber, we regard muscular contraction as only a special case of elastic shortening.

A closer experimental comparison of the changes undergone, on the one hand, by the elasticity of our string during thermal shortening, and, on the other hand, by muscular elasticity during physiological contraction, will teach us that, in each case, the changes are of exactly the same kind.

As regards striated muscles, it was Eduard Weber who, by his classic researches, established that their extensibility increases during contraction. The same is now proved to hold good of strings and other organic doubly-refractive substances during thermal shortening.

The curve of lengthening of all these objects inclines more sharply toward the abscissæ of the loads the higher the temperature. Both curves converge, and may finally even cross, i. e., a certain load being exceeded, we do not get contraction, but lengthening, as the effect of heating.

This circumstance explains the fact, sometimes observed by E. Weber, that living, tired, heavily loaded muscles of frogs lengthen instead of shorten as a result of electric stimulation. Considered from other theoretical points of view, this observation seems so paradoxical that its very validity has been questioned by some physiologists, but in the face of the direct and exact measurements of so scrupulous an observer and inquirer as Eduard Weber, we have no right to do this. According to our view of the origin of muscular force, this fact is not paradoxical at all, but might be foreseen.

The decrease of the shortening power and the increase of extensibility with increasing thermal contraction is, in the case of our lifeless doubly-refractive objects, accompanied by a decrease in the power of double refraction. According to Von Ebner's careful measurements, the same thing is the case with muscles during vital contraction. We may consider this fact, too, as an important proof of the fundamental resemblance between the process of contraction in our model and in the muscle, and at the same time as a further evidence of the existence of a causal relation between double refraction and contractility in general. But it is the physicist's task and not the physiologist's to penetrate further into the relations between optic and elastic properties.

(To be continued.)

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